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A TEXT-BOOK OF OPERATIVE DENTISTRY

McGEHEE

Renouard

This remarkable sketch is contributed by the distinguished artist, Mr. George A. Renouard.

The theme is that of the teacher and the pupil. The sinuous grace and authoritative poise of the central figure, the teacher, and the supercilious cynicism of the assistant to his left are well represented while the concentrated effort to master the lesson on the part of the class (save one to the right, the languorous dreamer and laggard) are readily apparent.

The scene is historical and depicts the early origin of dentistry among the ancient Chinese and Japanese people. The initiates were given boards of soft wood perforated with holes containing snugly inserted pegs which they were taught to extract with the thumb and finger. Later, boards of increasing hardness containing tighter inserts were substituted.

When sufficient adeptness was acquired to successfully accomplish this remarkable feat the pupils were allowed to extract teeth from the mouths of suffering patients in a similar manner. On attainment of the necessary skill and digital power to satisfy the master they were "graduated" and became exponents of this form of destructive dentistry.

Since that time it has required thousands of years to develop the profession to its present state, where restorative and curative ministrations greatly predominate. It is thought by many that the dentistry of the future will be largely preventive and the best minds of the science and art are concentrated on efforts to consummate this much desired wish and strongly propounded belief.

By the same author

A TEXT-BOOK OF
DENTAL PHARMACOLOGY,
MATERIA DENTICA
and
PHARMACO-THERAPEUTICS

A TEXT-BOOK

OF

OPERATIVE DENTISTRY

BY

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Second Edition, Revised

WITH TEN HUNDRED AND FORTY ILLUSTRATIONS

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DEDICATION

THIS BOOK IS DEDICATED TO THAT NUMEROUS COMPANY OF LOYAL MEN AND WOMEN, MY SOMETIME STUDENTS, DURING A PERIOD OF OVER THIRTY YEARS AS A TEACHER; MANY WHOSE SPIRITS NOW WANDER HAPPILY IN SHADY GROVES AND BRIGHT ELYSIAN FIELDS; OTHERS YET ENTHUSIASTICALLY PREPARING TO ENTER THE REALM OF ACTIVE PRACTICE; THE MAJORITY, STILL WORTHY DEVOTEES OF SCIENCE AND FAITHFULLY CONSECRATED TO THE SERVICE OF HUMANITY.

The Teacher.—"A teacher's work does not die with him. It lives long after, and may give great results. Voltaire says of Virgil that he was Homer's greatest achievement; Dante was Virgil's. In science, and in the teaching of science, we find the same. Medicine teems with instances. Boerhaave inspired Haller; Hunter, Jenner; Cullen, Rush; Bretonneau, Trousseau. Through his pupils a teacher lives; the man passes away, the teacher remains in his pupils and becomes part of them."—Da Costa.

PREFACE TO SECOND EDITION

The first edition of this book was exhausted and a second printing, with few revisions, was made in 1932. The continued demand for the work on the part of teachers, students and practitioners of dentistry has been gratifying to the author and publishers and has necessitated the publication of a second edition, which is herewith presented.

Many advances have been made in the field of Operative Dentistry within the past few years. These advances have been included in the present edition. They refer especially to recent research in biological, metallurgical and technical fields as applied to Operative Dentistry. Particularly has the valuable work of the Research Commission of the American Dental Association in the National Bureau of Standards been reviewed and its latest findings incorporated herein.

These evidences of our continued progress in an important division of Dental Science have resulted in many changes in the present edition. Some of the sections have been rewritten and the others brought up to date. Some of the illustrations in the previous edition have been removed and others substituted. Also, many new charts and graphs have been incorporated. These changes and additions reflect our present conceptions of the importance and scope of Operative Dentistry and justify a continued interest and confidence of the profession in this book. In the preparation of this edition, many of the important recommendations of the Curriculum Survey Committee of the American Association of Dental Schools have been incorporated.

The field of Operative Dentistry was formerly much broader in its scope than it is at the present time. It originally included most of the operations performed by the dentist at the chair, just as Prosthetic Dentistry formerly embraced all of the laboratory procedures. Owing to our constantly increasing knowledge and the consequent growth of dentistry as a profession, numerous subdivisions or specialties have arisen, which, although still really a form of operative procedure and, as such, a part of Operative Dentistry, are now taught as separate branches. Similar subdivisions have occurred in Prosthetic Dentistry, though not to so large an extent. As a result, the modern text-book on Operative Dentistry should now be rather definitely limited to a discussion of the diagnosis, prevention, and treatment of those affections of the oral cavity resulting from dental caries, erosion or abrasion; from exposure or infection of the dental pulp and its sequelae; and of manifestations of pathologic disturbances of the peridental membrane resulting from pulp diseases.

In view of these facts, this volume includes a section on Diagnosis, recognizing the far-reaching influence of oral diseases on general systemic disturbances via the nervous, vascular and lymphatic systems. The increasing knowledge and importance of preventive measures justifies the inclusion of a section on Oral Hygiene and Preventive Dentistry, together with a consideration of dietary and other measures for the development of a healthy tooth and bone formation which will offer a high resistance against the inroads of disease. The Periodontists have rapidly developed a specialty of their own, consequently, owing to the existence of adequate text-books covering this field, the subject is omitted in this volume.

Exodontia, Anesthesia and Planting of Teeth are now relegated to Oral Surgery, consequently there is now no longer the necessity for inclusion of these subjects in this work. The interpretation of radiograms is presented in the section on Diagnosis and also in connection with the description of the various pathologic conditions throughout the text. A discussion of the theory and technique of making roentgenograms is omitted, since this belongs to the field of Radiology. Orthodontia is now a recognized specialty of dentistry and is taught as such through the medium of adequate texts. However, in view of the fact that the majority of patients needing orthodontic treatment are first seen by the general practitioner, the importance of early diagnosis is discussed in the chapters on Diagnosis and Prevention and in the section on Children's Dentistry. Dental Anatomy, Dental Histology and Dental Pathology are now fully covered from other Chairs in the dental school and, consequently, since it must be recognized that they have no place in a work of this nature, they are excluded, except where it is found necessary to dwell on particular phases of these subjects to develop a clearer conception of their bearing on operative procedure.

The bulletin on dental education by the Carnegie Foundation for the Advancement of Teaching (Dr. William J. Gies) emphasizes the importance of dentistry as a special branch of medicine, also the functions of modern professional dental practice as a health measure. These obligations and relationships are stressed throughout this work. The bearing of oral foci of infection and reflex nervous disturbances (arising in and about the oral tissues) on general systemic disturbances is emphasized, as well as the importance and necessity for continued research in the still more or less undiscovered fields of Stomatology.

The needs of the general practitioner of dentistry are fully recognized, but the book has been planned primarily for the use of teachers and students in the dental schools. Following the chapters on Diagnosis and Prevention, the subject matter is presented in logical sequence and in the order it is usually taught in the college. Owing to the generally improved condition of tooth environment arising from hygienic care, which has resulted from a better knowledge of preventive measures, and the increased realization of the importance of maintaining the pulp in a healthy condition (not forgetting esthetic considerations) certain modifications of former methods of cavity preparation are described and recommended. The factors influencing these changes of cavity-forms are fully discussed in their proper place.

A more perfect systematization or standardization of all operative restorative procedures is presented. This represents more particularly a standardization of instrumentation for cavity preparation and manipulation of filling materials, and is offered to the profession with the confidence born of serious and thorough experimentation over a period of many years. The adoption of this standardized technic in laboratories and clinics will result in marked increase in efficiency and productive power on the part of each student, without lowering individuality or lessening initiative or originality. Further, it will enable the students to compass a greater volume of work within a given time. The adoption of this system will also help the practitioner to increase his efficiency with less effort and at a minimum of wear and tear on his nervous energies. The use of this method also enables the assistant to prepare in advance for the coming operation, by placing in proper order on the operating table the indicated instruments, thus saving the time and energies of the dentist for the operation to be performed.

Dentistry has a nomenclature of its own which should not be confused with that of other related branches of science. The author throughout this work has followed the nomenclature accepted and authorized by the various dental organizations responsible for its adoption. Particularly has the "Dental Terminology" adapted from the Basle Nomina Anatomica (BNA) published by Dr. H. Pierce Anthony for the Committee on Nomenclature of the American Dental Association, been consulted.

During the preparation of this work the writings of many authors were reviewed. Due credit has been given wherever possible, but since the work of each investigator in the field of science must be based upon the work of others, it has not always been possible to give credit, much to the author's regret. He is especially grateful to Doctor Finn J. Bronner, Doctor T. V. Joseph, Doctor Hyman Pines, Doctor John R. Cushing, Doctor August J. Bastien and Doctor L. R. Cipes for their interest, encouragement and assistance. Thanks are herewith extended to Doctor Harold K. Box, Doctor John Bethune Stein and others for the use of valuable photomicrographs; to Mr. Alvin Taylor, technician, Doctor Samuel C. Miller, Doctor A. L. Greenfield, Doctor Irving Rotner and to many other friends who have assisted in the preparation of models, photographs, roentgenograms and drawings.

W. H. O. McGehee.

New York, 1936.

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INTRODUCTION TO THE STUDY OF OPERATIVE DENTISTRY

Science is systematized and classified knowledge. It is penetrating and comprehensive information and understanding of definitely ascertained truths, duly arranged and classified.

Science is pure or applied. Pure science is knowledge of powers, causes or laws considered apart or as pure from all applications. Applied science is a knowledge of facts, events or phenomena, as explained, accounted for or produced by means of these powers, causes or laws.

Art is the adaptation of things in the natural world to the uses of life. It is the application of knowledge or power to practical purposes, or the scientific employment of human means to accomplish some desired end.

Science and art may be said to be investigations of truth; but science inquires for the sake of knowledge, art for the sake of skilled production. The most perfect state of science will be the most high and accurate inquiry into knowledge and a systematic and orderly arrangement of knowledge; the perfection of art will be the most apt and efficient system of rules for practice or performance. Since art is the application of knowledge to action or performance, art is in its highest sense a part or subdivision of science, its function being based on a recognition of scientific laws.

DENTISTRY A SCIENCE AND AN ART

Under the above definitions, obtained largely from Webster's Unabridged Dictionary, dentistry may be classified as a science and an art, although, as in medicine, our knowledge of the causes, manifestations and treatment of many of the conditions confronting us is still inadequate and incomplete. To quote the significant words of Victor E. Levine in the Scientific Monthly "The task of discovering particular facts and general laws, of systematizing, classifying, correlating and interpreting has just begun. The astronomer is still engaged in studying the infinitely great. The chemist and the physicist are still investigating the infinitely small—the molecule, the atom, the ion, the electron. The botanist, the zoologist, the physiologist, the bacteriologist are still increasing the rich harvest of interesting phenomena concerning complicated life processes. The psychologist is still delving into the motivity of human action. The embryologist is yet unfolding the first chapter of genesis. The geologist and the paleontologist are still extracting history from the rock of ages. These accumulated treasures, indeed, seem marvelous, and yet, as each year rolls by, we find ourselves, like Balboa, looking down on the Pacific from the mountain top, beholding its seemingly infinite and beautiful expanse, as yet unknown and unfathomed. We feel with Sir Isaac Newton like children gathering shells on the shores of an infinite sea. The vista continues to widen, and new problems, new theories, new viewpoints, loom large before us. To quote Joseph Priestley: 'In completing one discovery we never fail to get an imperfect knowledge of others of which we could have no idea before, so that we can not solve one doubt without creating new ones.'"

OPERATIVE DENTISTRY DEFINED

Operative Dentistry is that particular branch or specialty of the science and art of dentistry which aims at the preservation of the natural teeth and their supporting structures, or restoration to a state of health and beauty. It concerns those procedures which, applied to the natural organs of mastication and their surrounding or underlying tissues, prevent pathological processes of these parts; or if disease and deterioration have occurred, restores them, so far as possible, to a normal, physiological condition. Its functions, then, are both *preventive* and *restorative*, of which the former is receiving increasing attention and is beginning to be considered much more important. In order to intelligently apply preventive or restorative measures, it first is necessary to determine the causes and nature of the conditions to be dealt with. That is to say, a *diagnosis* of the disturbances must be made. Recognizing these fundamental principles, it is found that Operative Dentistry may be logically divided into three subdivisions, viz. (1) Diagnosis (determination), (2) Prevention (prophylactic procedures), and (3) Restoration (surgical or mechanical measures).

NECESSITY FOR RESTORATIVE PROCEDURES

If it is possible to discover means to prevent pathological disturbances in the mouth, the necessity for restorative procedures will be largely diminished. However, there will always be a demand for restorative procedures and curative measures in dentistry and medicine, no matter how great the knowledge and ability of the profession may be in applying preventive measures, since the public at large will not be willing at all times to follow the laws of health, and also because, as civilization progresses, changing conditions will produce new diseases that will demand additional and continued research on the part of the medical and dental professions to determine means for combating them.

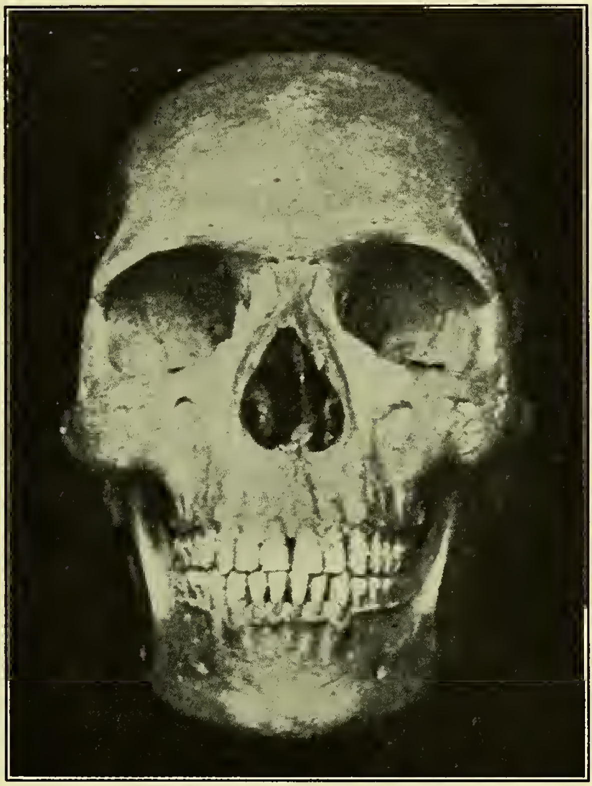

FIG. 1.—Adult skull, anterior view.

Medical and dental research are still in their infancy and must continue to meet the changes and developments incident to advancing civilization. These and all other forms of scientific research must, however, be based on the discoveries of preceding generations. The words of Doctor R. A. Millikan are significant in this connection when he says "In spite of all the new discoveries, there is a truth in the past which is not and cannot be ignored nor brushed aside. Much of the knowledge of the past is still eternal truth, and just as Einstein embraces all

Newton, so presumably the truth of the present is merely a supplement to and an extension of the truth of the past."

FUNDAMENTAL REQUIREMENTS

The successful and intelligent practice of Operative Dentistry is based on a thorough knowledge of the fundamental laws of science. This, of course, is equally applicable to the practice of all the specialties or subdivisions of dentistry. The student must be conversant with the principles of chemistry, physics and biology, and must be broadly educated in the fundamental medical subjects, such as anatomy, histology, physiology, hygiene, pharmacology, therapeutics, pathology and bacteriology. He, also, must have an adequate comprehension of the laws of physics, metallurgy, mechanics and engineering, and make frequent applications of them; further, he must possess and exercise to the highest degree, the artistic sense. Dentistry is really applied

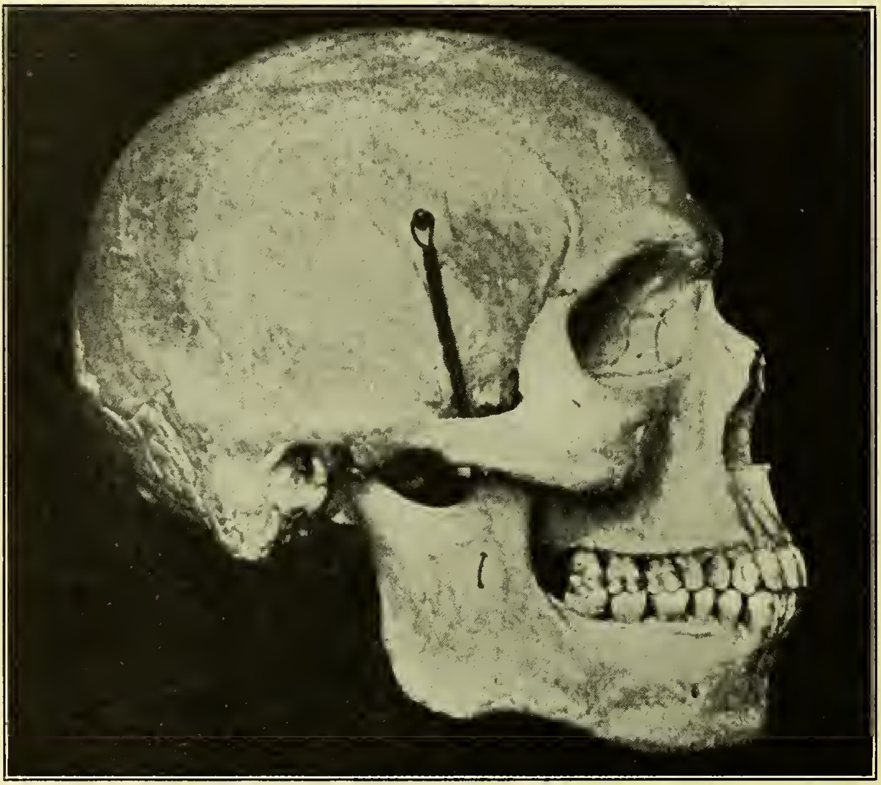

FIG. 2.—Adult skull, right side.*

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*The skull seen from different aspects in this section is from the collection and illustrated through the courtesy of Dr. Milo Hellman.

biology, functioning through the possession on the part of its devotees of great diagnostic and therapeutic ability, highly developed technical skill and the application of true artistic principles.

The dentistry of the past has been largely a science of the physical order. It is now recognized also that it is essentially of the animate order, with its source in biology, which deals with living organisms. Although a separate profession, it is, in its last analysis, a special branch of the healing art.

The following paragraphs from the Introduction to Science by J. Arthur Thomson are significant. "The too intensely practical man has got so accustomed to the fruits of science that he is apt to forget that these cannot be forthcoming if the roots die. Therefore to the critic who growls over the time spent on studying sea weeds, when 'what we want is more wheat;' over embryological research instead of fish hatching; over the theoretical puzzles of geology instead of the search for more coal and iron; we must answer, first, that man does not live by bread alone; second, that he must be patient if his desired practical results are to be sure; third, that Science is a unity, and the theoretical foundation is essential if there is to be progressive practical application; and, fourth, that, as a matter of fact, it has often been from the most unpromising theoretical investigations that great practical discoveries have come. Even for the sake of practice, Science should never submit to the over-practical man's canon which makes immediate utility a stringent criterion of worthiness."

"Blocked apart for practical convenience, treated in separate books, expounded by different teachers, investigated in different laboratories, the sciences are, after all, parts of one discipline, illustrations of one method, attempts to make clear—if never to solve—the one great problem of the *Order of Nature.* They form, or should form, one body of truth, and they gain in value the more they are correlated. This is the ideal alike of the Philosopher's Stone, of the Encyclopedia, of the University, and of the most modern scientific synthesis." . . . "The living creature cannot be isolated or studied in vacuo. It has an inanimate environment from which it is scientifically inseparable, and it sends its tendrils into the lives of many other creatures. If we are to come nearer knowing the truth about the living creature, we must study it in its interrelations. But that involves the convergence of many sciences, which approach their ideal completeness in proportion as they are correlated." . . . "We have to bear in mind that the living creature is passing by as one of a great historical pageant. It is an heir of the ages, only to be understood as the resultant of numberless factors—mechanical, chemical, physical, and animate—which have gone to its shaping. It has gathered into itself the sunshine and air, the wind and the rain of millennia. It requires a unity of the sciences if it is to be understood." In view of these thoughts, it is well to remember always that truly great scientists are men of humble mind in the presence of the much they cannot know.

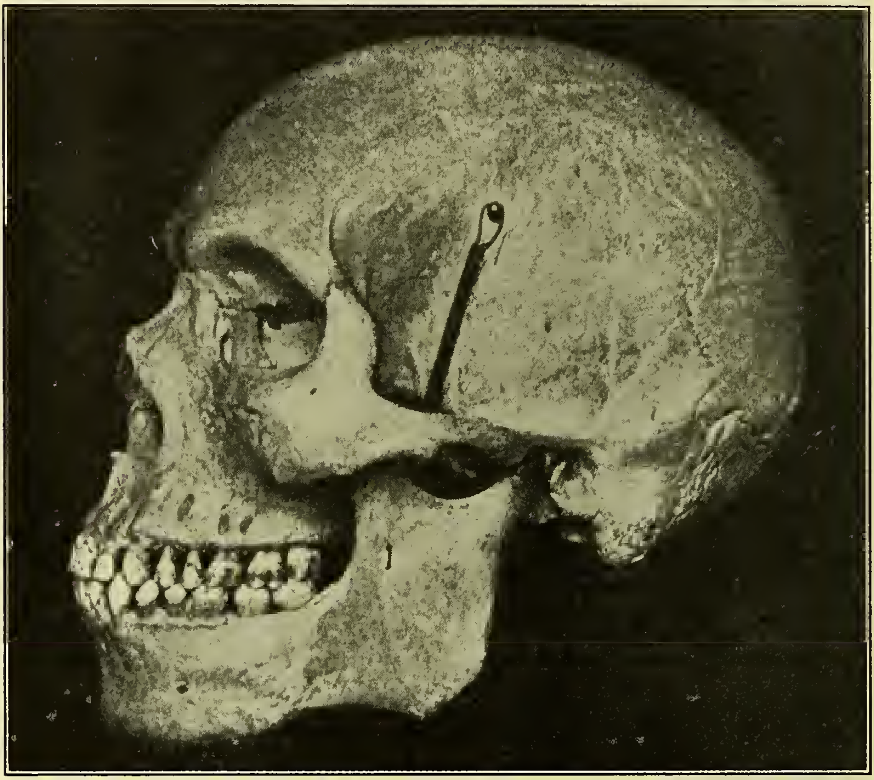


Fig. 3.—Adult skull, left side.

BIOLOGICAL RELATIONSHIPS

Although the principal field of action of the operative dentist is the oral cavity, it is necessary for one who aspires to succeed, to any great degree, in this particular branch of a noble and elevated profession, to become, at the beginning, deeply imbued with the all-important truth that the oral cavity is intimately and closely associated with all other parts of the body, by way of the nervous, vascular and lymphatic systems. This fundamental truth being perceived, two additional ones may then readily be deduced: *first*, that pathologic disturbances in the mouth have a far-reaching influence on the production of diseases of other tissues; and *second*, that the teeth and supporting structures are equally subject to disturbance of their normal functions from abnormal conditions in distant parts.

The average dentist, in the past, has been too frequently interested in the question of restoration of tooth structure through various mechanical procedures. He has possessed a very narrow view of the broad scope of his profession, and has not fully realized the importance of the great truths above inculcated, with the result that often he, himself, and the public at large, have not appreciated the dignity of his calling and its far-reaching influence on the health and well-being of society.

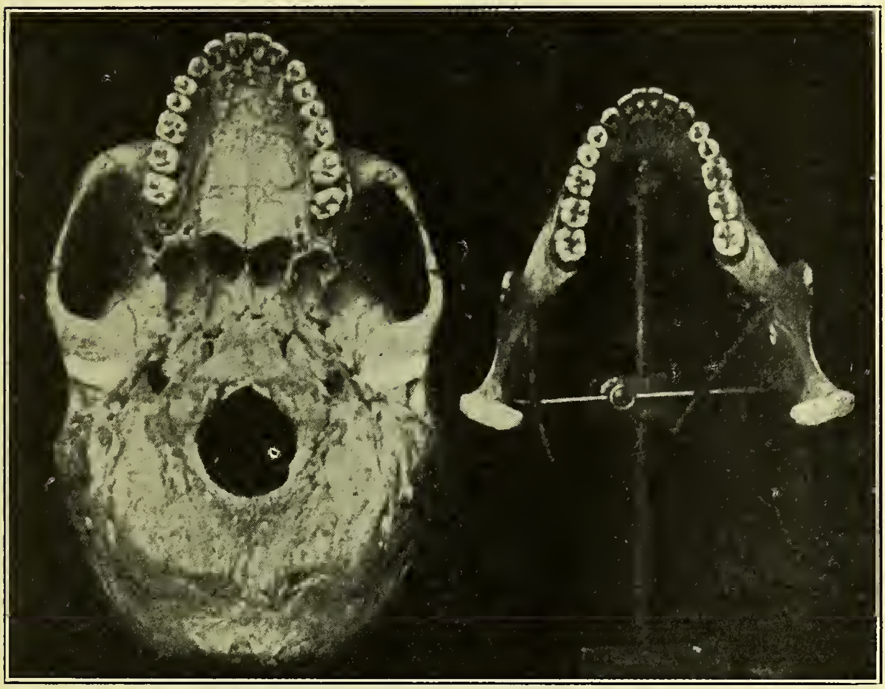


FIG. 4.—Adult skull.

It shall be the constant aim of the writer throughout the following chapters to emphasize the intimate connection existing between the various local and constitutional pathologic disturbances, and the likelihood of producing disease processes in other parts of the human organism, through an imperfect realization, on the part of the dentist, of the dangers of oral foci of infection and imperfect dental operations. And, vice versa, it shall also be his task to emphasize the important bearing that disease processes in distant parts continuously exert on questions of diagnosis and treatment of many of the oral manifestations of these systemic disturbances.

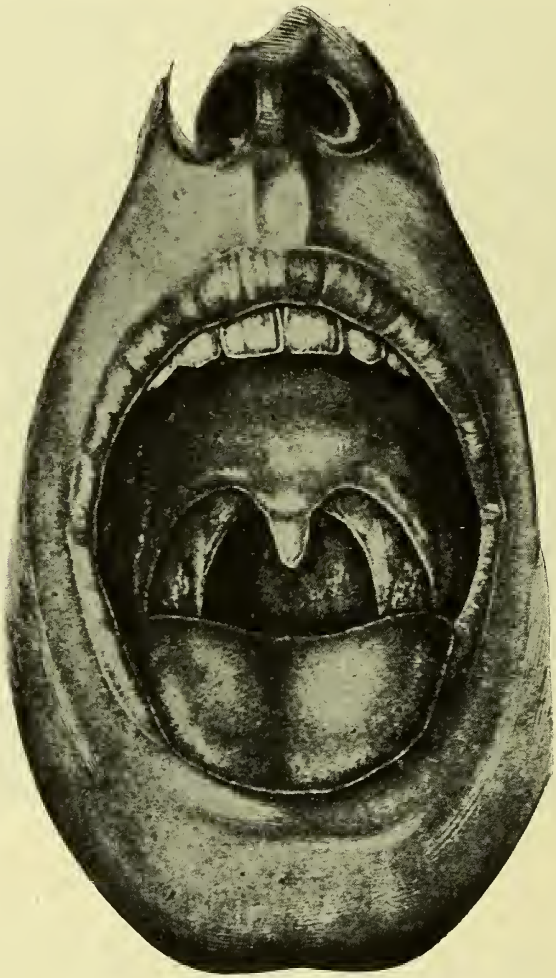


Fig. 5.—Anterior view of mouth. (Deaver.)

It is true that Operative Dentistry is, to a degree, concerned with a description of operations of a mechanical or surgical nature; but the reader should constantly bear in mind the fact that these operations are performed on vital tissues, and that always the health, and frequently the life of the patient is involved. Therefore, the patient has a legal and a moral right to expect and demand intelligent and scientific service, based on a full realization of the above truths, on the part of the operative dentist.

An inspection of the accompanying illustrations (Figs. 1, 2, 3, 4, 5, 6, and 7) will reveal the principal field of operation of the dentist, together with some of its relationships. Figs. 1, 2, 3 and 4 depict a remarkably beautiful example of bone and tooth formation. From an esthetic and sculptural standpoint they are well-nigh perfect examples of the handiwork of the Great Architect. It is well to observe that these remarkable organs of mastication are firmly implanted in and practically are an integral part of the bony structure of the skull, which itself is an integral part of the framework of the body, and intimately connected with all parts of the organism by means of the vascular, nervous and lymphatic systems.

Many students, on looking into the mouth, seem only to see a set of teeth, and this is true, unfortunately, with many men in the active practice of the profession today. Figs. 5, 6, and 7 illustrate many important structures which should be perceived or visualized on an inspection of the oral cavity. If this is done and the existing relationships and anatomical connections are constantly borne in mind, a much broader conception of the scope of dentistry as a scientific profession will be gained and maintained, and great good will result to the credit of the patient, the practitioner, the profession and the public at large.

IMPORTANCE OF THOROUGHNESS

The correct performance of the various operative procedures described in the following chapters requires the development of the highest degree of manual skill and dexterity, great delicacy of touch and manipulation being essential. Each individual step or stage of every operation must be completed in detail, before proceeding to the next, if a perfect result is to be attained in the finished operation. Dentistry is a profession of detail, and in no vocation is a realization of the importance of detail in the performance of the manifold mechanical procedures more essential. So delicate are many of these manipulative procedures, that the use of high-power lenses frequently is required to perfect the work before it can be called a finished product. It is hoped that this will be perceived by the reader and constantly borne in mind during the performance of the various technical operations.

ARTISTIC QUALIFICATIONS

The possession and development, to a very high degree, of the artistic sense is essential to the successful practice of Operative Dentistry. Courses in drawing, modeling, carving and shading are now included in the pre-dental courses or in the curricula of modern dental colleges, in order that an adequate comprehension of line, contour, proportion, shade and color may be obtained by the student. The artistic contour of a filling, the proper shading of a procelain restoration are of equal importance to the perfect mechanical adaptation of the finished product. The completed piece should so harmoniously blend in with the work of nature, that original line and color are preserved or restored and the work of the operation is as inconspicuous as possible. "The highest function of art is to conceal art."

DENTISTRY AS A PROFESSION

In practice, the dentist must be deeply imbued with the dignity and importance of dentistry as a profession. The Century Dictionary defines a profession as "a vocation in which professed knowledge of some department of science or of learning is used by its practical application to the affairs of others, either in advising, guiding, or teaching them, or in serving their interests or welfare in the practice of the art founded on it. It involves professed attainments in special knowledge, in contrast with mere skill—a practical dealing with affairs in contrast with mere study or investigation, and an application of such knowledge to uses for others as a vocation in contrast to its pursuit for one's own purposes." A trade, on the other hand, "is specifically the craft or business which a person has learned and which he carries on as a means of livelihood or for profit, particularly mechanical or mercantile; a handicraft, as distinguished from one of the liberal arts or the learned professions."

DENTISTRY A HEALTH SERVICE

The main idea involved in the above definitions distinguishing a profession from a trade is the idea of *service* to others—service to the patient, to the profession, to the public at large, to the state and to humanity. This should be the prime and activating motive in professional practice, and not the idea of the dollar. The late Chief Justice Taft said that "The most disturbing element in our life as a nation is the materialistic philosophy which places wealth and worldly success ahead of every other consideration in life. What can it profit a man to have accumulated millions if he has not at the same time maintained a clear conscience and acquired the good will and esteem of his fellow citizens?" Dentistry is just as much a health service as are any of the other branches of medical practice and this thought should be always paramount. The material reward should ever be a secondary consideration and will automatically adjust itself, being entirely

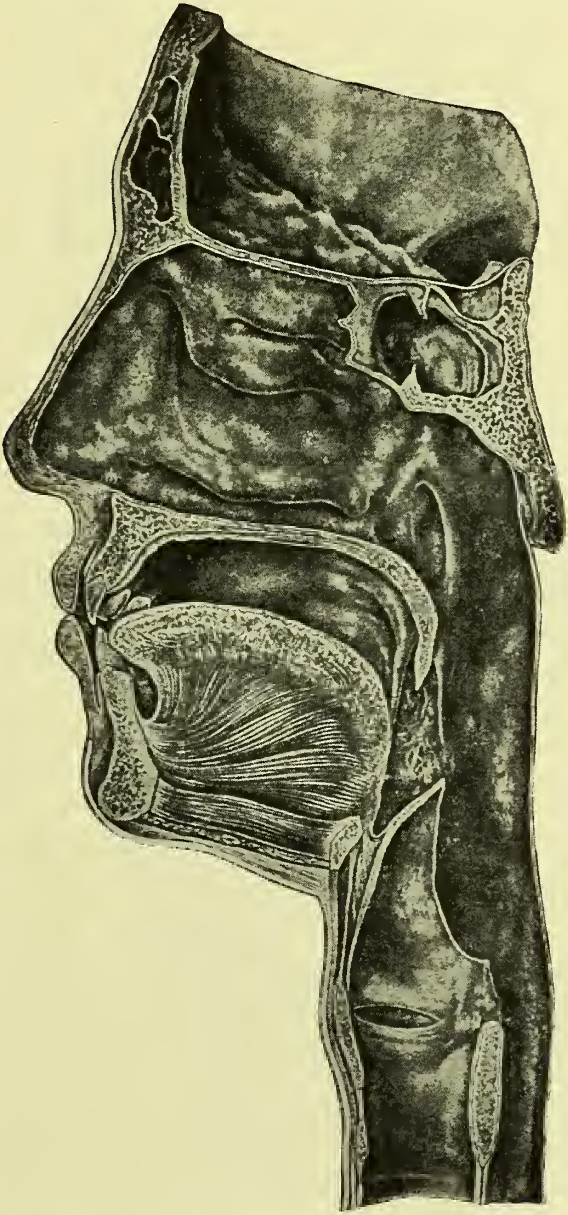


FIG. 6.—Vertical section of mouth, pharynx, larynx and nose. (Deaver.)

dependent on the type and class of service rendered. He serves his profession best who gives of the best that is in him and does so always with the thought of giving and not with the idea of deriving ultimate benefits.

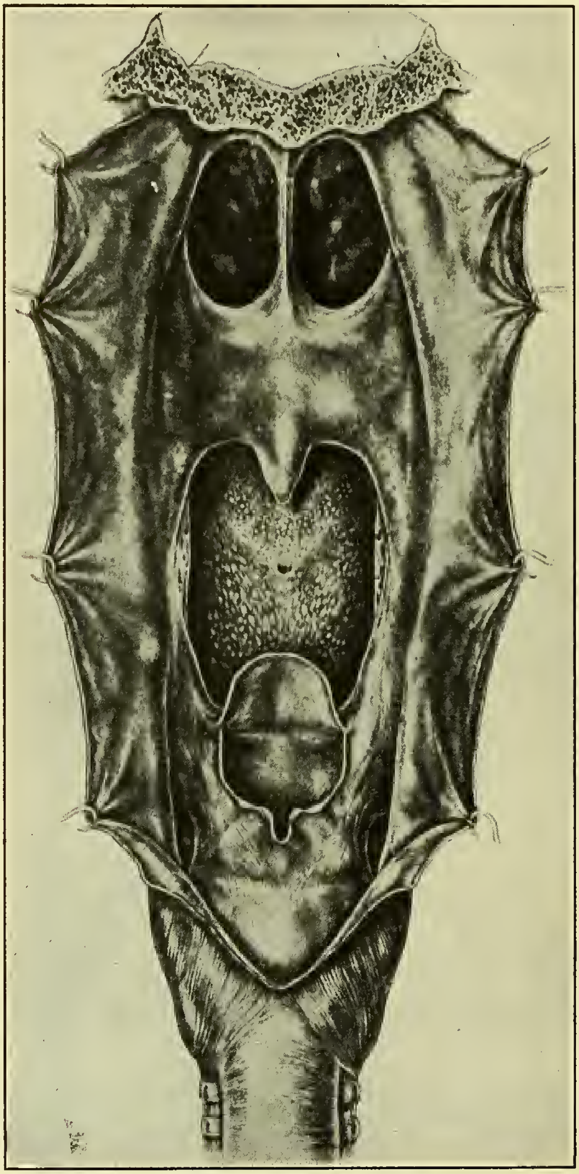


FIG. 7.—Interior of pharynx. (Deaver.)

CULTURAL AND ETHICAL ATTRIBUTES

Cultural and ethical objectives leading to the development of character should be included in all educational efforts. During the course in Operative Dentistry, the teacher and students should constantly bear this in mind. Habits of concentration and study, of observation, thought, logical reasoning and clear judgement should be cultivated. On the development of these mental faculties are the growth of the higher ethical faculties and attributes dependent. The attainment of these latter attributes, which are truly of the soul, will guide the student and practitioner in all his ethical and moral relationships—his relationships with his fellowmen, his patients, and his profession. They will lead him to develop a philosophy of life, to interest himself in the topics of the day, to become familiar with good music, to love and appreciate good paintings, sculpture and literature, to stand for manliness, integrity and uprightness and to be recognized as a high-principled, cultured gentleman. Doctor George David Stewart, great surgeon, poet and philosopher of New York University, said in an address to the graduating class of Dalhousie University, Halifax, that "Life is lived in terms not of science, but of human relationships. Science changes, that of today will not suffice for that of tomorrow, but the emotions of the heart are eternal, and we weep today over the tragedies of Sophocles as unrestrainedly as they wept in the amphitheaters of ancient Greece. Greater than the sciences, older than the sciences, the Bible and the Classics are still the great moulders of character. That man is educated who is furnished with a philosophy of life. He has a dynamic force which will add to character, knowledge, and to knowledge, wisdom. Verily, if you have character, all other things shall be added unto you."

It is now perceived that the necessary attributes to the practice of dentistry are manifold. To be successful one must be deeply grounded in the roots of science and must possess the scientific mind and true professional spirit; he must be a close observer of phenomena and a good diagnostician; he must recognize the bearing of oral conditions on the general health and well-being of his patients; he must intelligently exercise the functions of the competent oral physician; he must be a skilled and efficient technician, a sincere artist, a humanitarian and a cultured gentleman with highly developed moral instincts and attributes. It is the earnest wish of the writer that this be fully recognized and that the reader of the following pages will diligently apply himself to their realization and attainment.

Bibliography

Waite, Frederick E.: The relation of biology and dentistry, Dental Summary, 1920.
Owre, Alfred: What is dentistry? Minneapolis District Dental Jour., 1923.
Waite, Frederick E.: Biologic preparation for the study of dentistry, Jour. Amer. Med. Assoc., vol. 87, pp. 335–339
Holmes, Oliver Wendell: The claims of dentistry, Harvard University Dental School Bulletin, Feb. 1872.
Waite, Frederick E.: Development of dental education in the U. S., School Life, vol. XI, no. 4, pp. 61–63, Dec. 1925.
Conzett, Jno. V.: The importance of operative dentistry, Jour. Amer. Dent. Assoc., Nov. 1929, p. 2020.
Cecil, Russell L. and Miner, Leroy M. S.: Inter-relation of medicine and dentistry, Jour. Dental Research, vol. 10, no 2, April 1930, p. 137.

OPERATIVE DENTISTRY

CHAPTER I

DIAGNOSIS IN OPERATIVE DENTISTRY

In the Introduction, it was determined that the scope of Operative Dentistry included three principal fields, viz.: Diagnosis, Prevention and Restoration. Methods of diagnosis and of examination of the patient are discussed in this and the following chapter.

IMPORTANCE OF DIAGNOSIS

It is self evident that before preventive means can be intelligently instituted, or curative or restorative procedures resorted to, it is first necessary to make a thorough diagnosis of the case. The examination of the patient is then, a very important procedure and should be considered very carefully and thoroughly. It should include not only a close inspection of the teeth and supporting structures, but also a general inspection of the patient, in order that a clear picture may be obtained both of the local conditions and their bearing on and connection with systemic conditions. In making the examination, the minutest defects and most obscure pathologic disturbances should be detected and recorded, in order that they may receive immediate attention. It is a great mistake to defer to a later date operations on minor disturbances. They can be remedied in their inception with much less pain to the patient and trouble to the operator, and will enable the patient to maintain more readily proper hygienic conditions in the mouth.

DERIVATION, SCOPE AND QUALIFICATIONS

The word diagnosis is derived from the Greek, *dia* meaning through, apart, between, across, asunder; and *gnosis*, meaning knowledge. Diagnosis literally means through knowledge and signifies the art of distinguishing one disease from another, or of the determination of the nature of a case of disease by means of distinctive marks or characteristics. These are the usual definitions of the word as applied to medicine and dentistry, but a more liberal translation would signify scientific determination of any kind, whether applied to professional, commercial, political, martial, peaceful, or any other type of condition or pursuit.

An intimate study of the lives of all the great men of history will reveal the fact that they have been successful diagnosticians. I now use the term in its broader sense. If one will analyze the character of the great leaders in any line of endeavor, as revealed by the heights to which they have risen, as recorded in their biographies, he will find that this statement is true. The eminence which these men and women have attained has been the result of an inherent ability or genius to get to the bottom of things—to recognize conditions, to find their causes, and through logical reasoning, to deduce the exact effect or result on these conditions of certain definite processes, or actions.

The successful Diagnostician in medicine or dentistry must be endowed with many important qualifications.

First.—He should be armed with *exact* knowledge; that is to say, he should be intimately conversant with the fundamental biologic sciences and with the characteristics of disease processes in general. How is it possible to intelligently diagnose disease of an eye, or a tonsil, or a tooth without thorough knowledge of the physiologic and pathologic reactions of the entire organism?

Second.—He should be endowed with the faculty of close, accurate and discriminative observation. He must have the ability to observe accurately, analytically and in an orderly manner, these observations being accomplished by means of the visual, auditory, olfactory, tactile and gustatory senses.

Third.—He should possess the power of quick intuition. This does not mean that he should ever guess at conclusions, but that he should have, through experience, the power to directly perceive or recognize the probability of a truth or condition.

Fourth.—He should have a thorough appreciation of values, and a just sense of proportion; else, frequently, errors will arise through failure to give points in diagnosis their true appraisal. Failure in this regard would often result in the laying of too little or too much stress on conditions and relationships.

Fifth.—He should be enabled to make comparisons. The conditions under consideration should be compared with manifestations previously seen in other disturbances.

Sixth.—He should have a genius for minutiae, with the realization that large inferences may occasionally be drawn from small facts. This involves a consideration of form and structure and a correlation of these with functions and the relationships to similar and dissimilar structures.

Seventh.—He should never guess at conclusions. This would, in all likelihood, lead to biased judgement and, possibly, to a determination to find what had been guessed at.

Eighth.—He must possess the power of judgement in interpretation of phenomena. Judgement is the result of deep thought and long experience.

Ninth.—He must not allow sentiment to dominate reason, but in every case must reach conclusions calmly, coolly and impartially, regardless of personalities or possible consequences.

Tenth.—His powers of deduction and induction must be developed to a very high degree, his train of thought must be consecutive, and he must be largely capable of logical reasoning from cause to effect and *vice versa.*

PERCEPTION AND APPERCEPTION

These are the requisites to the highest attainments in this field. They may be developed to a degree through conscientious, intelligent and persistent application. All mental activity is based on the result of sense perception with which it begins. Perception is the first form of knowledge. The senses of seeing, hearing, tasting, smelling, and feeling furnish us with that which we call the individual notion, or concept. Sense perception is followed by inner or intellectual conception, viz. apperception. As a result of reflection this is followed by the general notion, or general conception, embracing definitions, laws and principles. If we call all within the field of consciousness perception, then activity within the focus of consciousness, or the point of greatest clearness may be termed apperception. All attempts to improve methods of diagnosis must be based on the perceptive power of the senses and the apperceptive power of the mind. These methods should begin with the individual notion, lead through the general to the universal, and finally return to the individual application. The passage from the individual to the general should be made through the exercise of comparison, imagination or intuition, thought, reason and insight, thus developing the powers of deduction and induction. The return to the individual application results from the employment of derived universals to new particulars. In considering the individual notion, both analytical and synthetic methods of reasoning should be brought into play.

DIAGNOSIS IN ITS INFANCY

Methods of diagnosis are still in their infancy in the profession of dentistry. In reviewing the literature, one is impressed with the increasing references to diagnosis of oral disturbances by various contributors to this field in recent years. This is a very healthy sign, but it must be admitted that, as yet, we have made a very small beginning. Only by increased attention to diagnostic procedure can the profession advance much further in the field of prevention. In the final report of the Curriculum Survey Committee of The American Association of Dental Schools a very definite and comprehensive course on Oral Diagnosis is recommended for inclusion in the curricula of all the member schools of the Association. The adoption of such a course will lead to much good and result in the proper training in this field of the young men and women who are to be the future practitioners of dentistry.

It is difficult to determine what effect these efforts have had on the minds of the rank and file of the profession. My experience and observation of conditions convince me that the examination of patients by the average practitioner is a very cursory and superficial procedure, consisting mainly in an exploration for cavities of decay. Even the presence of calculus is frequently either overlooked or ignored. The introduction of the X-ray into dentistry has undoubtedly resulted in great good in this direction, and probably has been the greatest single factor in the stimulation of interest in the importance of correct diagnosis. The examination of patients applying for dental attention should not be the cursory procedure frequently observed by many practitioners. Recognition of the existence of oral foci of infection and their far-reaching influence on the health and well being of the entire organism, as well as increasing knowledge of many vague manifestations of reflex disturbances associated with oral pathologic conditions have become of such importance in their bearing on the practice of dentistry that it is difficult to foretell what is to be the future status of the profession. It will undoubtedly become in the near future one of the most important of all the medical specialties in its bearing on the health of the nation.

For purposes of description the various procedures in diagnosis may be classified under two distinct headings, as follows:

1. Routine diagnosis for ordinary cases, and
2. Special diagnosis for systemic disease.

The latter division will now be considered, leaving the routine methods for a subsequent chapter.

PERSONAL AND FAMILY HISTORY

For patients suffering with periclasia, or other readily apparent conditions, as well as for those affected with disturbances of a vague nature, it is often important, in addition to the routine procedures, that an extremely minute examination be made, which may include personal and family history, blood pressure findings, dietary considerations, blood, salivary and urinary tests, pathological, bacteriological, serological, immunilogical, and toxicological analysis as well as radiographic; and oral inspection. The number and type of these tests will vary, depending on the nature of the case under consideration and the character of information desired. The use of a history chart is essential for comparison with the laboratory findings, as well as a matter of record. The laboratory tests may be referred to workers specially trained in this field, if desired. The diagnosis should be based on a comparison of the history chart, the clinical and laboratory findings, and a complete set of radiograms. Do not be determined to find what you suspect. This is an error frequently made by inexperienced diagnosticians and pseudo-scientists in the fields of research. A definite and orderly routine should always be followed in making a classification of cases, this being combined with sound analytical reasoning and judgment in interpretation of findings. Satisfy yourself as to whether the radiographic findings are corroborative or negative of the laboratory findings and as to whether they agree with or contradict the clinical findings.

A very important procedure in making a systemic examination for obscure conditions is the obtaining of a complete personal and family history, all of which information should be recorded on the case history chart provided for that purpose. The age, sex, habits, environment, occupation, weight and height all have a definite bearing on the physical condition and may disclose valuable information as to the nature of the oral disturbance. The health, cause and age of death, previous illnesses, or present health of parents and relatives will frequently reveal certain hereditary tendencies. The temperature, pulse, respiration, and blood pressure will be of great value in their bearing on other findings.

Inspection or inquiry as to the condition of the joints, such as the shoulder, elbow, wrist, fingers, thigh, knee, ankle and foot, as well as of the muscles is important, as it may reveal the presence of arthritis. The condition of the eyes, ears, nasal passages, skin, tonsils, and thyroid glands may be ascertained by direct examination or by leading questions, revealing the presence or absence of headaches, blurring, or inflammation of the pupil, eyestrain, ringing in the ears, faulty hearing, discharge or bleeding from the nose, tonsillitis, enlarged thyroid, and similar disturbances. The condition of the heart and respiratory apparatus may be ascertained through the use of the stethoscope. In special cases, where deemed necessary, the patient may be referred to a specialist who is experienced in making a physical examination of the heart and lungs.

DIAGNOSIS OF SYSTEMIC DISEASE

Cases which demand special examination for systemic disease are:

1. Patients who present oral lesions which are suspected as being concerned in the production of foci of infection in other localities.

2. Patients presenting oral lesions which may be causative of reflex nervous disturbances (reflex neuroses) in other parts.

3. Patients who manifest systemic disturbances of an inflammatory, infective or nervous type which may be productive of oral manifestations.

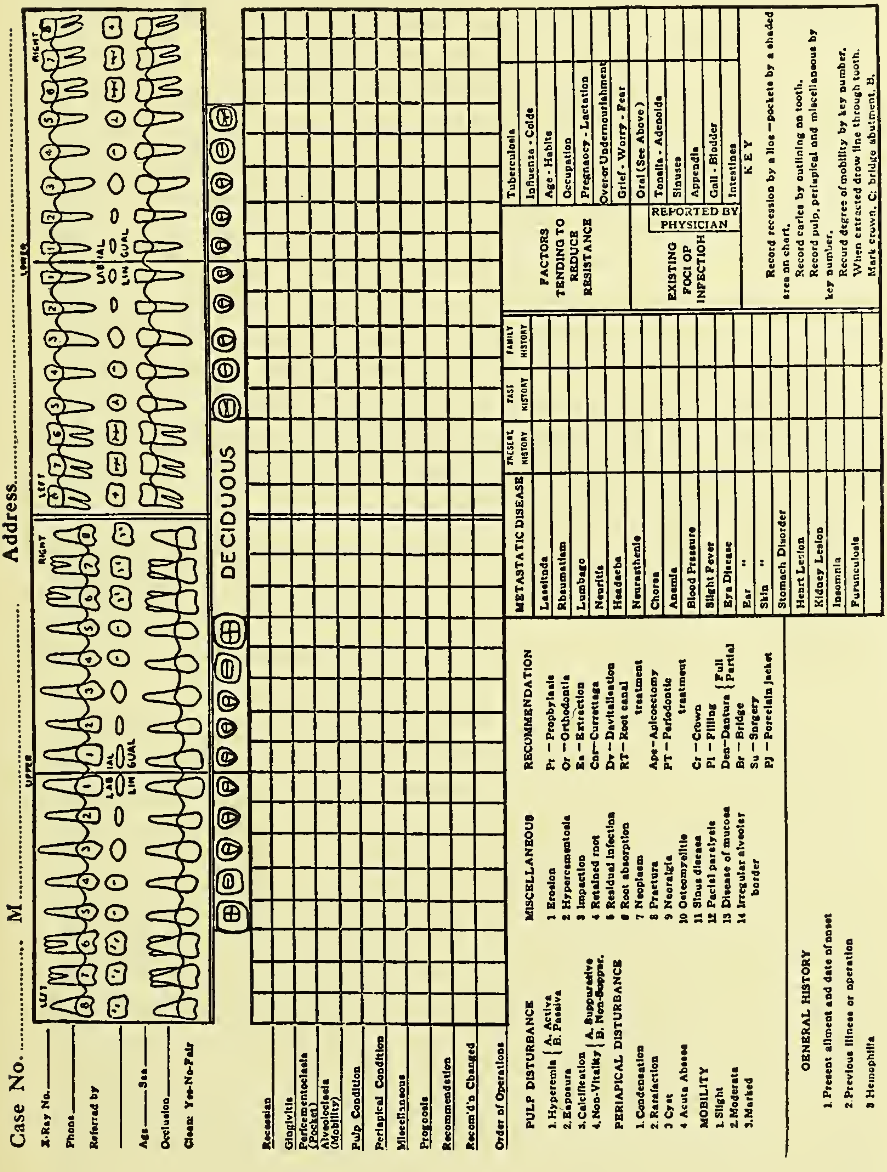
4. Patients suffering with systemic complications which may be factors in lowering the resistive powers of the body, resulting in increased susceptibility to pathologic attacking agencies, diminished response to oral therapeutic measures and lowered ability to subject themselves to serious or prolonged dental operations.

Diagnostic Charts.—In making the examination, the following general outline of procedures may be followed and noted:

1. Name, address, nationality, age, sex, occupation.
2. Chief complaint.
3. Previous history of general health.
4. Present conditions, onset, duration and progress; previous treatment.
5. Family history.
6. Habits and environment.
7. Symptoms, objective and subjective.
8. Laboratory tests—blood, urinary analysis, saliva, Wasserman reaction.
9. Metastatic Disease.
10. Roentgenographic examination.

The chart herewith illustrated (Fig. 8) is valuable for recording local conditions and systemic manifestations as they appear in the clinic. It may be modified to suit individual needs. Its method of use may readily be determined by inspection.

Leading Questions.—For determination of systemic disease, it will frequently be necessary to refer the patient to the physician, the interne or to the laboratory technician for a complete diagnosis. However, much valuable information may often be obtained through tactful use of leading questions, which may give in many cases the information


RIGHT
LEFT
UPPER
LOWER
LABIAL
LINGUAL
DECIDUOUS

Case No. .... M. .... Address........

X-Ray No.____
Phone____
Referred by
Age____Sex____
Occlusion____
Clean: Yes-No-Fair

Recession
Gingivitis
Pericementoclasia (Pocket)
Alveoloclasia (Mobility)
Pulp Condition
Periapical Condition
Miscellaneous
Prognosis
Recommendation
Recom'd'n Changed
Order of Operations

PULP DISTURBANCE
1. Hyperemia { A. Active / B. Passive
2. Exposure
3. Calcification
4. Non-Vitality { A. Suppurative / B. Non-Suppur.

PERIAPICAL DISTURBANCE
1. Condensation
2. Rarefaction
3 Cyst
4 Acute Abscess

MOBILITY
1. Slight
2. Moderate
3. Marked

MISCELLANEOUS
1 Erosion
2 Hypercementosis
3 Impaction
4 Retained root
5 Residual infection
6 Root absorption
7 Neoplasm
8 Fracture
9 Neuralgia
10 Osteomyelitis
11 Sinus disease
12 Facial paralysis
13 Disease of mucosa
14 Irregular alveolar border

RECOMMENDATION
Pr — Prophylaxis
Or — Orthodontia
Ex — Extraction
Cur—Curettage
Dv — Devitalization
RT — Root canal treatment
Apc—Apicoectomy
PT — Periodontic treatment
Cr — Crown
Fl — Filling
Den—Denture { Full / Partial
Br — Bridge
Su — Surgery
PJ — Porcelain Jacket

GENERAL HISTORY
1 Present ailment and date of onset
2 Previous illness or operation
3 Hemophilia

METASTATIC DISEASE	PRESENT HISTORY	PAST HISTORY	FAMILY HISTORY
Lassitude			
Rheumatism			
Lumbago			
Neuritis			
Headache			
Neurasthenia			
Chorea			
Anemia			
Blood Pressure			
Slight Fever			
Eye Disease			
Ear "			
Skin "			
Stomach Disorder			
Heart Lesion			
Kidney Lesion			
Insomnia			
Furunculosis			

FACTORS TENDING TO REDUCE RESISTANCE
Tuberculosis
Influenza - Colds
Age - Habits
Occupation
Pregnancy - Lactation
Over-or Undernourishment
Grief - Worry - Fear

EXISTING FOCI OF INFECTION
REPORTED BY PHYSICIAN
Oral (See Above)
Tonsils - Adenoids
Sinuses
Appendix
Gall - Bladder
Intestines

KEY
Record recession by a line—pockets by a shaded area on chart.
Record caries by outlining on tooth.
Record pulp, periapical and miscellaneous by key number.
Record degree of mobility by key number.
When extracted draw line through tooth.
Mark crown, C; bridge abutment, B.

FIG. 8.—Diagnostic and case history chart.

desired, or may lead to a decision as to whether it is necessary to refer the patient for a more thorough examination. Important information may frequently be elicited by diplomatic questions as follows·

The Alimentary Canal.—If disease of the alimentary canal is suspected, the questions may be directed to the obtaining of the following information, viz. (*a*) appetite, (*b*) character of meals, (*c*) pain, fullness or discomfort, (*d*) location and radiation of pain, (*e*) vomiting, (*f*) flatulence, (*g*) state of the bowels, (*h*) pain in the abdomen.

The Liver.—If liver or gall-bladder affections are suspected, questions may be directed towards eliciting the following points, viz. (*a*) character of pain, whether severe and lasting a few hours or not, radiation, located in the shoulder or associated with vomiting; (*b*) yellowness or jaundice following the attack; (*c*) presence of hemorrhoids; (*d*) presence of digestive disturbances; (*e*) color of urine or faeces.

The Respiratory System.—If the symptoms indicate respiratory trouble, obtain the following information, viz. (*a*) presence and character of cough, when worse and if painful; (*b*) color of expectoration, presence of blood, and whether after severe coughing; (*c*) pain in the chest, its location and if on deep breathing; (*d*) dyspnoea, night sweats, loss of weight and strength, hoarseness and fever.

The Cardio-vascular System.—If disease of the cardio-vascular system is suspected, obtain the following information, viz. (*a*) presence or absence of dyspnoea, (*b*) precordial discomfort or pain, (*c*) palpitation and its relation to meals and exercise, (*d*) headaches and giddiness, (*e*) digestive disturbance, (*f*) nose-bleeding, (*g*) swelling of the feet and ankles.

The Kidneys.—Obtain the following information, viz. (*a*) presence or absence of drowsiness, headache, dimness of vision, dyspnoea, vomiting, paralysis, or convulsions; (*b*) puffiness of the face, swelling of the ankles, color and amount of the urine, frequency of micturition, pain in the lumbar region with radiation to the groin.

The Nervous System.—Elicit the following, viz. (*a*) presence of headache, character, when worse and where located, (*b*) nausea or vomiting, (*c*) dizziness, (*d*) difficulty in walking, (*e*) visual disturbances, (*f*) convulsions, general or local, age of beginning, frequency and character, (*g*) discharge from the ears.

The Bones and Joints.—Obtain the following, viz. (*a*) location of pain in the bones or joints, whether worse at night, when the joint is moved, or continuous, starting pains at night, whether affected by the weather, and whether shifting from one joint to another.

Factors Reducing Resistance.—On the completion of the above questionnaire, the patient may be referred to the internist or physician for more definite information, if deemed necessary or advisable. The possible existence of foci of infection should always be definitely determined. Knowledge of the condition of the tonsils, posterior fauces, sinuses, appendix, gall-bladder and intestinal tract is frequently of great importance in its bearing on oral disturbances and treatment, consequently it should be definitely determined. These conditions may be concerned in production or accentuation of the oral disturbance, or the oral condition may be productive of the systemic manifestations. Many bodily ailments or conditions may be factors tending to reduce the resistance of the patient against disease processes and against the response to treatment. These should be recognized and thoroughly investigated, such as common colds or grip, senility, adolescence, pregnancy, lactation, neurasthenia, habits (drug or otherwise), alcoholism, occupation, convalescence, tuberculosis, faults of metabolism producing under-nourishment, nervousness, grief, worry or fear.

Metastatic Complications.—Symptoms indicating the presence of possible metastatic disease should receive adequate attention by the oral diagnostician or be determined by referring to the general diagnostician. The disturbance may be due to an association with some oral focus of infection and even if there be no connection between the local and systemic condition, the presence of metastatic disease should be recognized as a condition which is lowering the resistance and vital powers of the entire organism. Cases presenting with symptoms of lassitude and unusual fatigue from slight exertion, mental and physical inertia, melancholia, insomnia, loss of weight, greyish sallow skin, anemia and slight temperature, should be suspected of carrying a local focus of infection resulting in a general toxemia. The infective focus may be located in or about the teeth, or it may be in some other locality.

Patients manifesting symptoms of arthritis, neuritis, neurasthenia, anemia, stomach or intestinal disorders, heart or kidney lesions, furunculosis, chorea, inflammatory or septic disturbances of the eye, ear or skin, should be investigated for the presence of possible metastatic disease.

Continued absorption of toxins and micro-organisms via the gastro-intestinal tract, the lymphatics or the vascular system will ultimately throw great strain on the organs whose function it is to combat disease, and lead to affections of these organs and generally lowered resistance. The naso-pharynx, the gastro-intestinal tract and the oral cavity are considered the most frequent and important sources of infection. Diseases of the eyes, such as conjunctivitis, iritis, choroiditis, or keratitis may be due to metastatic infection or to reflex nerve irritation. It is the duty of the dentist to investigate disturbances of this nature and bring them, if necessary, to the attention of the physician, as to the possibility of their bearing on dental ministrations.

THE TEMPERATURE, PULSE AND BLOOD PRESSURE

Taking of the pulse, the temperature, the respiratory rate and the blood pressure will often be important and lead to more definite determinations. Blood examination, the Wasserman test for syphilis, and urinary analysis will occasionally be indicated. Salivary analysis will ultimately become of great value as an index for the determination of metabolic conditions, since the salivary content is derived from the blood stream. This should be a subject for extended research, since very little information is at hand in the literature at present.

The Temperature.—Taking the temperature with a fever thermometer may reveal the presence of fever or sub-normal temperature, the average normal temperature being 98.6 degrees Fahrenheit. Changes in temperature are produced largely through metabolic processes and are regulated by the vaso-motor and trophic nerves and the secretory nerves of the sweat glands.

The Pulse.—The pulse may be taken by placing the first, second and third fingers of the right hand over the radial artery of the relaxed wrist of the patient. Its frequency, regularity of beat, size and tension, should be noted, since they represent the condition of the heart-muscle and valves, the arterial muscular tone and pressure of the blood stream. The average rate of the pulse in adults is seventy-two beats per minute, its frequency varying in different individuals with age, convalescence, malnutrition, and great bodily exertion. A frequent pulse may be due to muscular activity, exhaustive diseases and debilitated states. It is almost always found in fevers, neurotic and toxic conditions, exophthalmic goiter, conditions of weak heart muscle and in valvular diseases when compensation is failing. A perpetually irregular pulse usually indicates valvular defects of the heart. Occasional interruption or omission of the beat is not usually considered serious, its cause often being unknown or sometimes attributed to excessive use of tobacco, coffee, and other stimulants. The size of the pulse, large or small, is dependent on the amount of blood delivered to the arteries by the ventricular systole of the heart. A large pulse is often seen in hypertrophy of the left ventricle and in high fevers. The small pulse often accompanies attacks of syncope and is seen in cardiac muscular weakness, in mitral and aortic stenosis. The tension of the pulse may be noted by applying pressure with the proximal of the three fingers used in taking the pulse and noting the effect of this pressure on the ability to appreciate the pulse with the distal finger. A hard pulse is eliminated with difficulty by this method. Chronic nephritis and arterio-sclerosis usually exhibit the hard pulse, while a soft, easily compressible pulse is found in fevers, anemia and conditions of weak heart muscle. The character or consistency of the arterial wall may be determined by applying pressure farther up the arm while keeping the palpating fingers in position, thus eliminating the arterial blood temporarily from the radial arteries. A normal radial artery is not palpable when empty, while the so-called pipe-stem artery of arterio-sclerosis and old age is easily felt.

The Blood Pressure.—By blood pressure is meant the pressure exerted by the blood on the walls of the vessels in which it is flowing. The *systolic pressure* is the pressure in the arteries produced by the contraction of the heart during systole, and it represents the total heart's energy. The *diastolic pressure* represents the blood pressure in the arteries during diastole, or the period of rest of the heart. It is the total of the peripheral resistance or forces acting against the heart. The *pulse pressure* indicates the extent to which the heart overcomes peripheral resistance and represents the total efficiency of the heart action.

The taking of the blood pressure requires experience in the use of the stethoscope and the sphygmomanometer (blood pressure machine). For detailed methods of taking the blood pressure and their significance, the reader is referred to works on clinical diagnosis. The systolic, diastolic and pulse pressures should be determined for exact results by the auscultatory method through listening with a stethoscope to the characteristic sounds produced. The normal *systolic* blood pressure in adults varies from 105 to 145 mm., as indicated on the dial of the sphygmomanometer, being slightly less in females and increasing with age. It is subject to rather wide variation and is affected by xercise, excitement, time of day, posture, temperature or climate, humidity and altitude. A method of determining systolic pressure for a given age is to consider 120 mm. as normal for a person 20 years of age. For every two years above this age, add 1 mm. At 40 years the pressure should be approximately 130 mm., at 50 years it should be about 135 mm., etc. The normal adult *diastolic* pressure varies from 60 to 105 mm., while the *pulse* pressure is the difference between the two and averages from 25 to 40 mm. For instance, if the systolic pressure is 120 mm. and the diastolic pressure is 80 mm., the pulse pressure is calculated as 40 mm. When normal relationship exists between these three pressures, the pulse pressure should equal about one-third of the systolic pressure, while the diastolic pressure should be approximately two-thirds of the systolic pressure. Wide variations in blood pressure should be considered as danger signals and require investigation as to their causes. A persistent systolic blood pressure over 150 mm. (hypertension) should be regarded as pathological and its cause sought. The usual causes of persistent hypertension are to be found in pathologic conditions of the cardiovascular-renal system. These may be due to toxemia from some error in intestinal or urinary metabolism, or to toxemia from some local focus of infection. Low blood pressure (hypotension) is usually found in lowered tone of the body from any cause, such as typhoid fever, hemorrhage, pneumonia, tuberculosis, valvular heart lesions, collapse under anesthetics. Patients suspected of having heart lesions should be referred for thorough examination through the usual methods of palpation, percussion, auscultation, taking of the blood pressure, the making of electrocardiograms and similar procedures.

The alarming death rate due to heart disease is inducing an increasing number of physicians to turn to the electrocardiograph for aid in diagnosing their heart cases. Besides helping the physician to distinguish between forms of heart disease that are serious and those of minor importance, it is of inestimable value to the surgeon in picking up unsuspected heart lesions in his preoperative cases, especially in his aged, goitre and fibroid cases.

EXAMINATION OF THE REFLEXES

Examination of certain reflexes is another procedure on which stress should be laid. Improper response of these reflexes indicates the presence of derangements of the nervous system. Those tests or signs which are most frequently utilized are:

1. *Argyl-Robertson's*, which is a failure of the pupils to react to light, and seen in locomotor ataxia.
2. *Crichton-Brown's*.—A slight tremor at the angle of the mouth and eyes, seen in the beginning of paresis.
3. *Moebius'*.—Inability to converge the eye-balls; met with in exophthalmic goiter.
4. *Joffroy's*.—Inability to wrinkle the occipito-frontalis muscles of the forehead, seen in exophthalmic goiter.
5. *Von Graefe's*.—Failure of the eyelids to follow the eye-ball downward. Also seen in exophthalmic goiter.

6. *Jaw Clonus* (jerk).—Reflex contraction of the muscles of mastication, produced by a downward stroke of a light hammer on the mandible hanging passively or supported gently by the hand. It is rarely present in health and is increased in sclerosis of the lateral columns of the spinal cord. The motor tonus of the trifacial nerves (fifth) may also be tested by having the patient close the teeth tightly and feeling the tenseness of contraction of the masseter and temporal muscles.

7. *Rhomberg's.*—Swaying of the body when the patient stands with the feet together and the eyes closed. Seen in ataxia.

8. *Patella reflex.*—Diminution or increase of the patella reflex (knee jerk), seen in different forms of ataxia.

9. *Babinski's.*—Extension of the great toe with flexion of the other toes on exciting the sole of the foot. Seen in certain forms of ataxia and paralysis.

10. The motor tone of the *facial nerves* (seventh) may be tested by having the patient close the eyes tightly, wrinkle the forehead and elevate the upper lip, noting any lack of symmetrical action. Test the *vagus* nerves (tenth) by having the patient say "ah," noting if both sides of the palate are raised equally. The *hypo-glossal* nerves (twelfth) may be tested by having the patient protrude the tongue, noting the presence of atrophy or any deviation to either side.

11. The sensory functions of a part may be tested with a feather or with cotton lightly passed over the area. A pin point may be used to test for areas of analgesia, hyperalgesia or delayed conduction. Temperature sense may be determined with test tubes containing warm and cool water.

REFLEX DISTURBANCES

Only a brief discussion of the diagnosis of reflex neuroses is admissable, consequently it will be possible to mention only a few of the salient features of the subject. Extensive research in this field is necessary, since it is now recognized that probably as many vague manifestations are due to transmissions via the nervous system, as are those arising from focal infection. Success in diagnosis here largely depends on a knowledge of the anatomical relationships of the nerves of the parts involved. The nerves which especially concern us in this discussion are the *fifth*, or trigeminus and the *seventh*, or facial (Figs. 9, 10 and 11). These nerves are in intimate connection with each other and with the third, fourth, sixth, ninth and tenth, with the result that irritations affecting them are liable to produce neurotic results in the brain, salivary

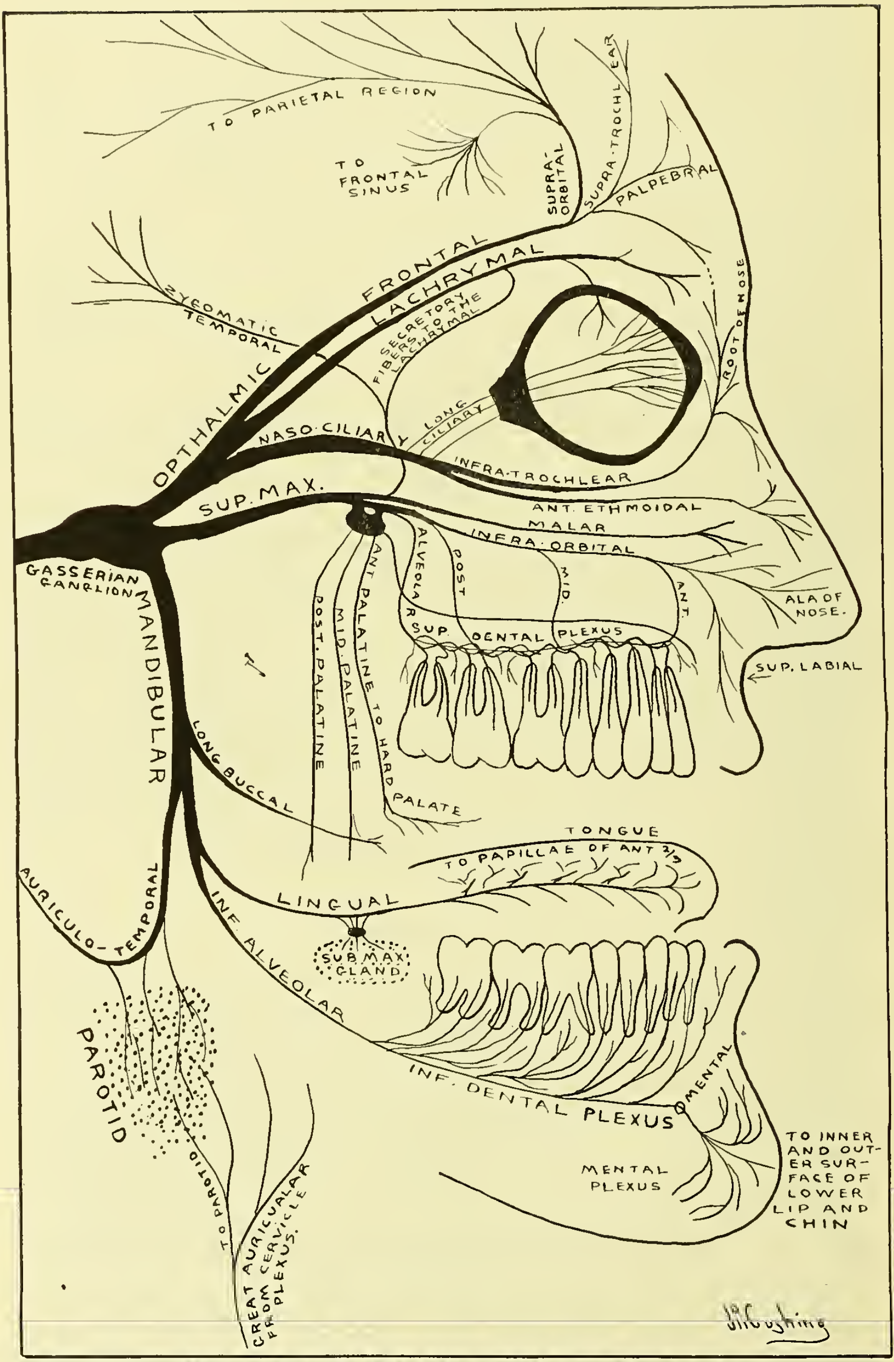


Fig. 9. Diagram of the fifth cranial nerve (trigeminus).

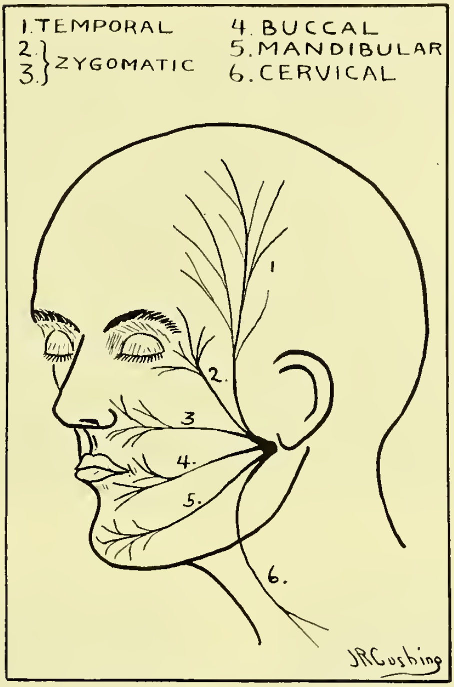


FIG. 10.—Distribution of the seventh (facial) nerve.

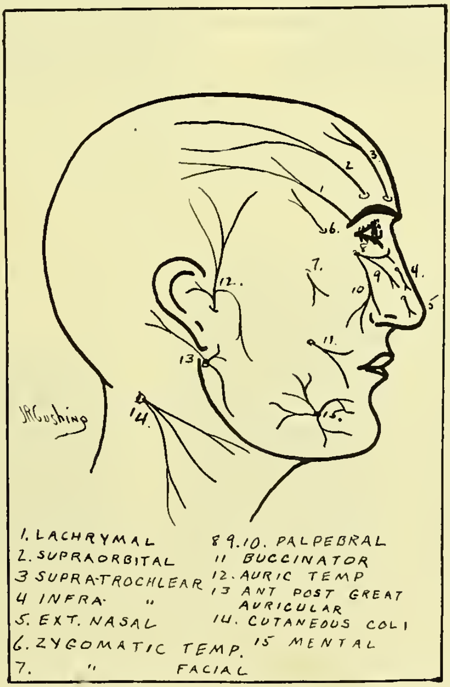


FIG. 11.—Terminal endings of the facial (seventh cranial) nerve.

glands, skin, lungs, large intestines, muscles of the face and extremities, through transmission of the impulses along the course of this extensive anatomic network of fibres. Some of these reactions may be explained through the fact that closely associated with the fifth nerve are four *sympathetic ganglia*, viz., the opthalmic, Meckel's, the otic and submaxillary.

Classification.—Reflex neuroses may be classified into:

(*a*) *Sensory Reflexes.*—Manifesting themselves in the form of pain or analgesia in distant parts, while pain may or may not be present at the point of irritation.

(*b*) *Motor Reflexes.*—Manifesting themselves in the form of muscular excitation or sedation in parts distant to the cause.

(*c*) *Nutritive or Trophic Reflexes.*—A form of reflex in which the trophic or vasomotor nerves are reflexly irritated so as to cause trophic or nutritive disturbances.

Those reflex disturbances immediately concerning the dentist may be classified into:

First.—Tooth disturbances the result of pathologic conditions in distant parts.

Second.—Reflex disturbances in distant parts originating from pathologic conditions of the teeth and supporting structures.

Of these, the latter are the more numerous and more frequently observed, although many dental disturbances are due to distant causes.

REFLEX DISTURBANCES IN THE TEETH AS A RESULT OF DISEASE IN DISTANT PARTS

These may be located in the teeth or indefinitely located about them. They may originate from the following sources:

1. From another tooth.
2. From optic and nasal disorders.
3. From visceral disturbances.
4. From cerebral disease.
5. From systemic disorders.
6. From disease along the course of any part of the fifth nerve.
7. From affections of the maxillary and other sinuses.

1. *From Other Teeth.*—Reflexes from one tooth to another are a common disturbance, since the pulp is not supplied with the tactile sense. See Fig. 12. Particularly are they noted in the chronic constructive diseases of the pulp. Reflex disturbances manifesting themselves in the form of arterial hyperemia, inflammation, pulp nodules, secondary dentin, hypercementosis and similar conditions may be the

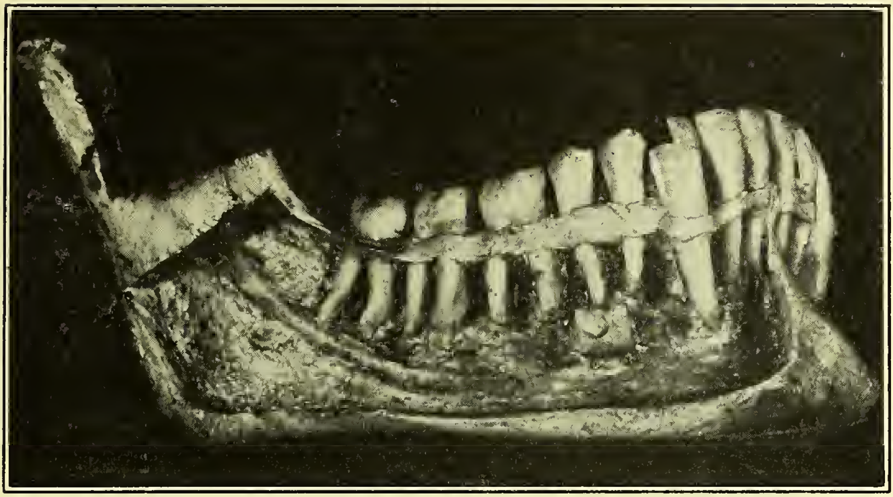


FIG. 12.—Right side of mandible showing roots of teeth, inferior dental canal and mental foramen.

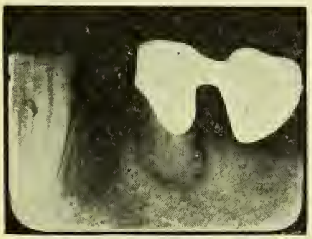


FIG. 13.—Hypercementosis.

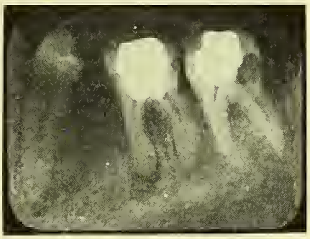


FIG. 14.—Hypercementosis and granulomas of roots of first molar. Filling on second molar probably involves pulp. No evidence of canal fillings.

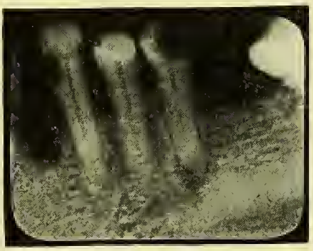


FIG. 15.—Chronic alveolar abscess, second bicuspid. Caries, mesial and distal of cuspid.

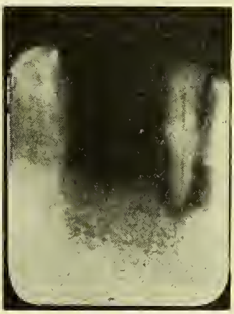


FIG. 16.—Marked alveolar absorption.

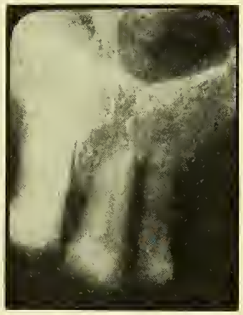


FIG. 17.—Marked alveolar absorption.

result of irritation in adjoining teeth. A pyorrhea pocket or alveolar abscess may also produce various neuralgias, as well as reflex vascular disturbances in distant teeth. Figs. 13, 14, 15, 16 and 17.

2. *Optic and Nasal Disorders.*—Reflex neuralgias in the teeth may result from nasal operations, catheterizations of the nasal duct, accidents to or operations on the eye, ulceration of the cornea and similar conditions. Figs. 18, 19, 20, and 21.

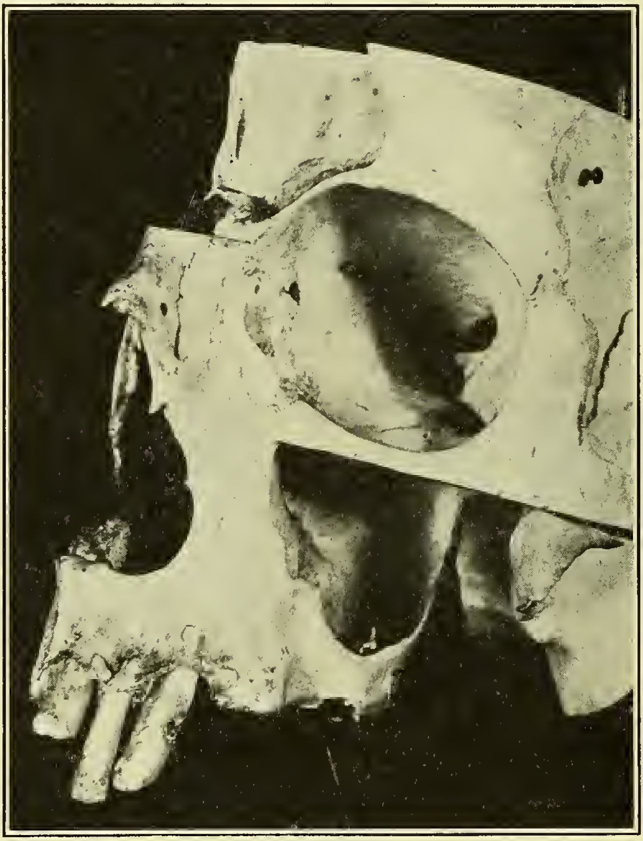


Fig. 18.—Showing close relationship of the maxillary antrum, the orbits, the nasal cavity and the teeth.

3. *Visceral Disturbances.*—Reflexes in the teeth in the form of neuralgia and hyperemic conditions are frequently the result of constipation, dyspepsia, sea-sickness, hunger, distended bladder, pregnancy, and uterine disturbance.

4. *Cerebral Disease.*—Embolism or thrombus in the brain, tumors, inflammation, or softening of the brain, hysteria, insanity, and other

conditions of similar nature may result in the production of reflex disturbances in or about the teeth.

5. *Systemic Disorders.*—Gout and arthritis may be mentioned as causative agents. Malaria often results in periodic attacks of neuralgia or inflammatory disturbance about the teeth. Syphilis frequently produces reflex disturbance of a pericemental nature. The exanthematous diseases (measles, chickenpox, scarlatina, etc.) may also be mentioned as being causative of these conditions. Anemia, coryza, (common cold) and influenza, also produce reflexes in the pulp and pericementum.

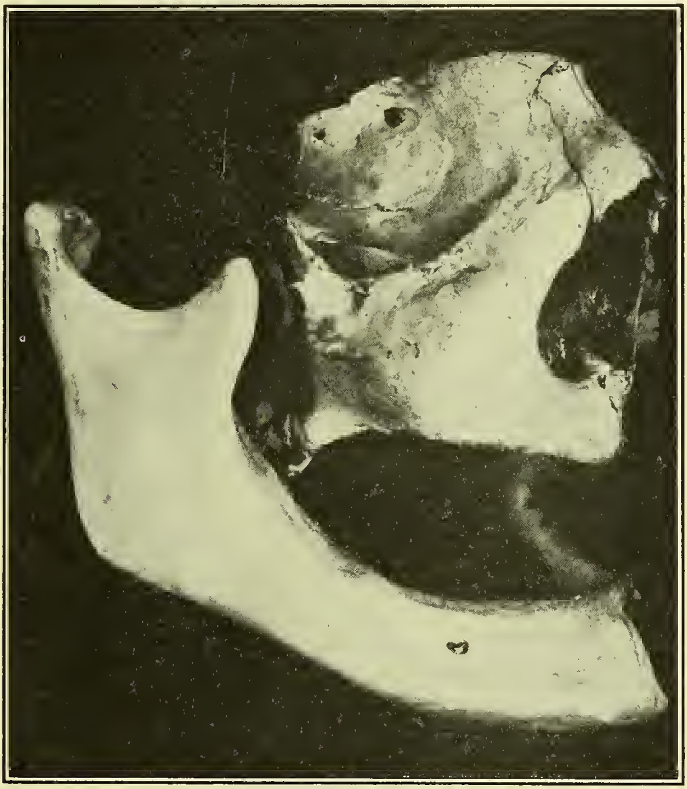


FIG. 19.—Edentulous jaws.

6. *Disease along the Course of the Fifth Nerve.*—Dental reflexes often result from inflammation of the nerve trunk, neuritis, pressure of tumors on the nerve, fracture of the maxilla or mandible, fracture cicatrices and bone whorles. Fig. 22.

7. *Affections of the Maxillary and Other Sinuses.*—Inflammation, infection, or abscess of the maxillary and frontal sinuses are familiar examples of conditions producing reflex disturbances in the teeth. Fig. 23.

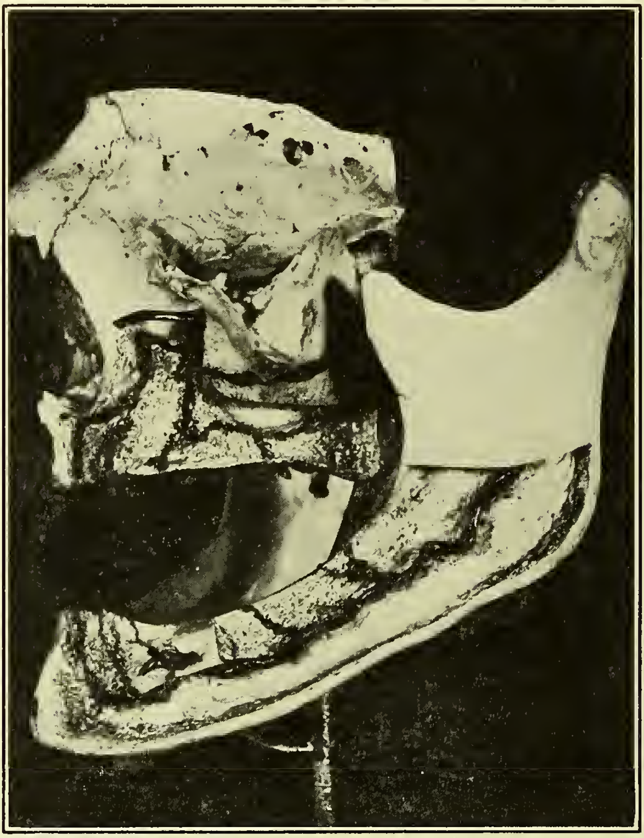


Fig. 20.—Edentulous maxilla and mandible, showing vascular and nerve supply.

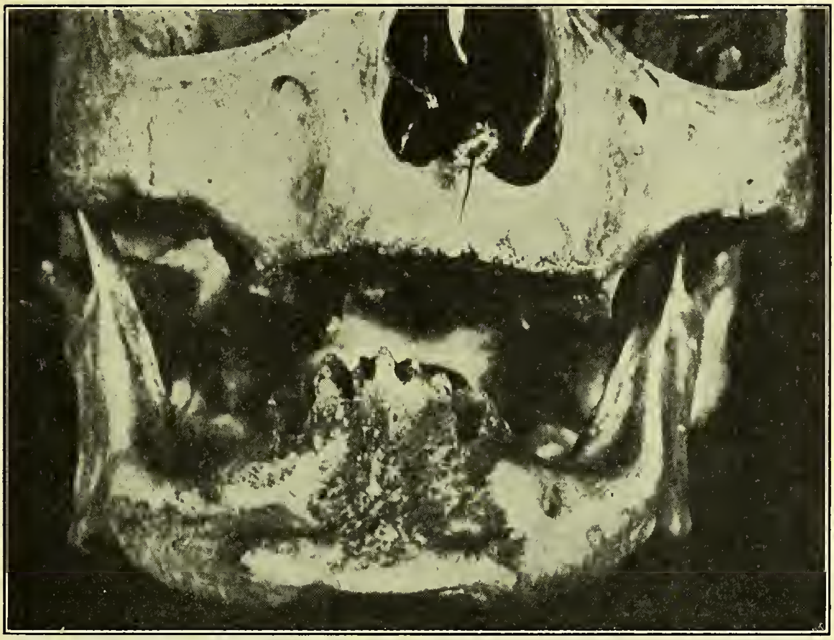


FIG. 21.—Part of an edentulous skull. The six lower anterior teeth were in position at death, but were lost during preparation of the skull. The infra-orbital foramina, nasal spine and septum and mental foramina are seen.

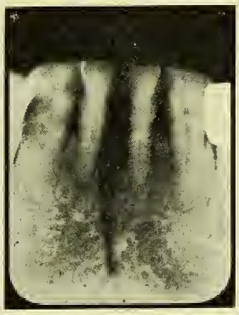


FIG. 22.—Alveolar fracture.

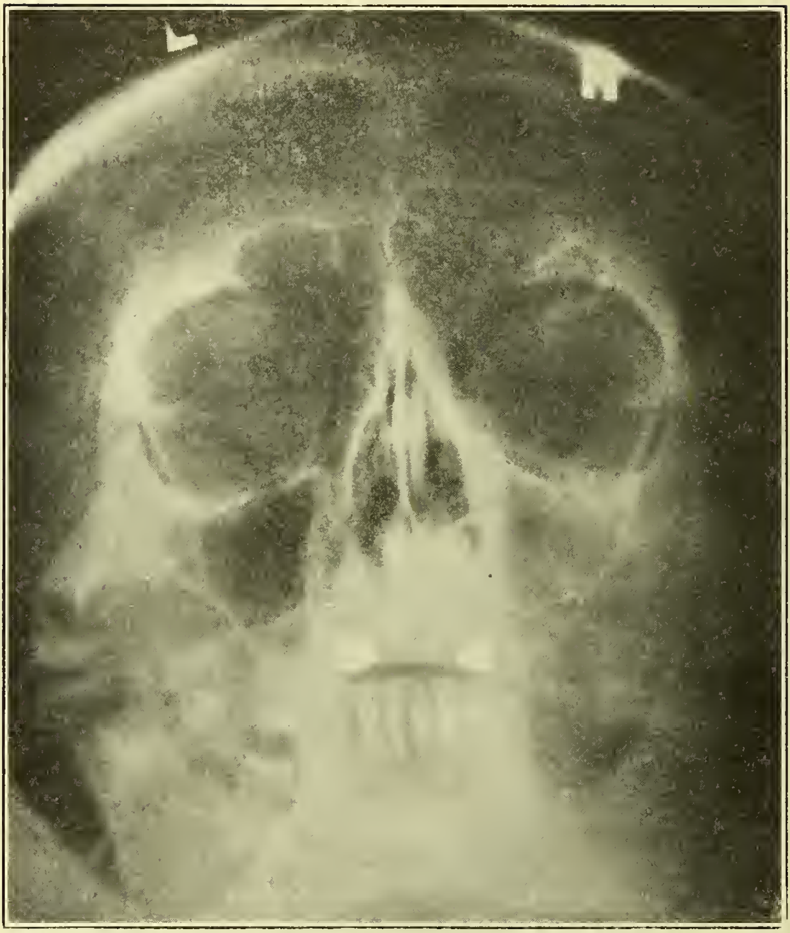


FIG. 23.—Maxillary sinusitis, right side. Left maxillary and frontal sinuses normal

REFLEX DISTURBANCES IN DISTANT PARTS RESULTING FROM PATHOLOGICAL DISTURBANCES ABOUT THE TEETH

The character of the tooth disturbance producing the reflex is interesting and often important in making a diagnosis. The pathological disturbances about the teeth producing these conditions may be mentioned as:

1. Diseases of the pulp.
2. Diseases of the pericementum.
3. Dentition.
4. Impacted teeth.
5. Crowded arches

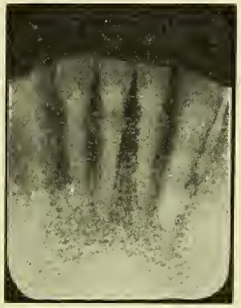


FIG. 24.—Salivary calculus on roots and alveolar absorption.

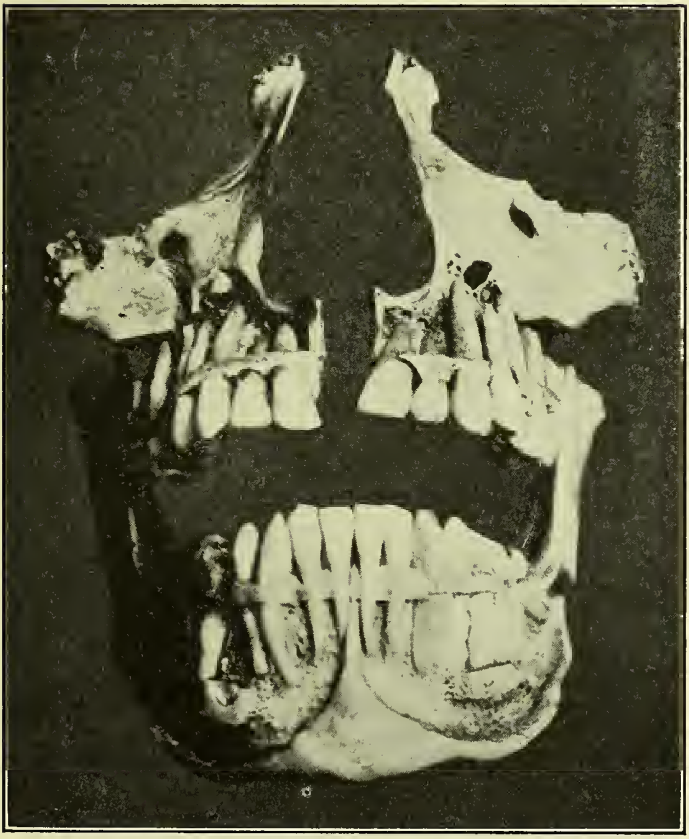


FIG. 25.—Maxilla and mandible of child.

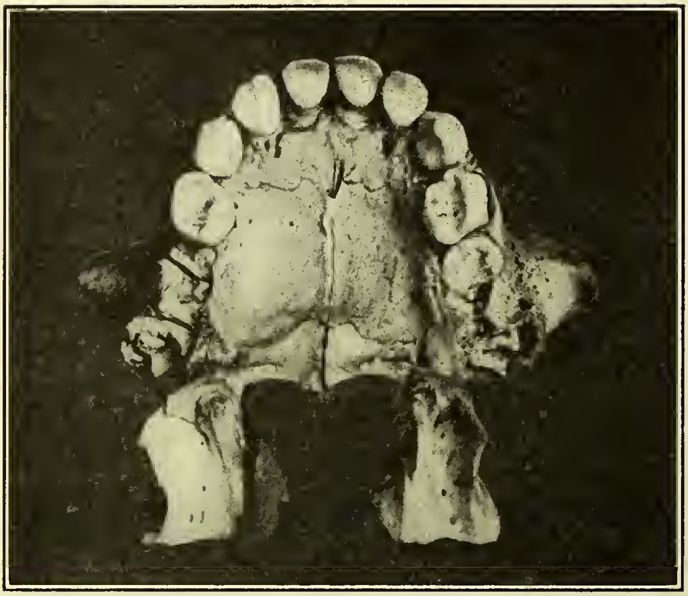


FIG. 26.—Infant maxilla. Age about two years.

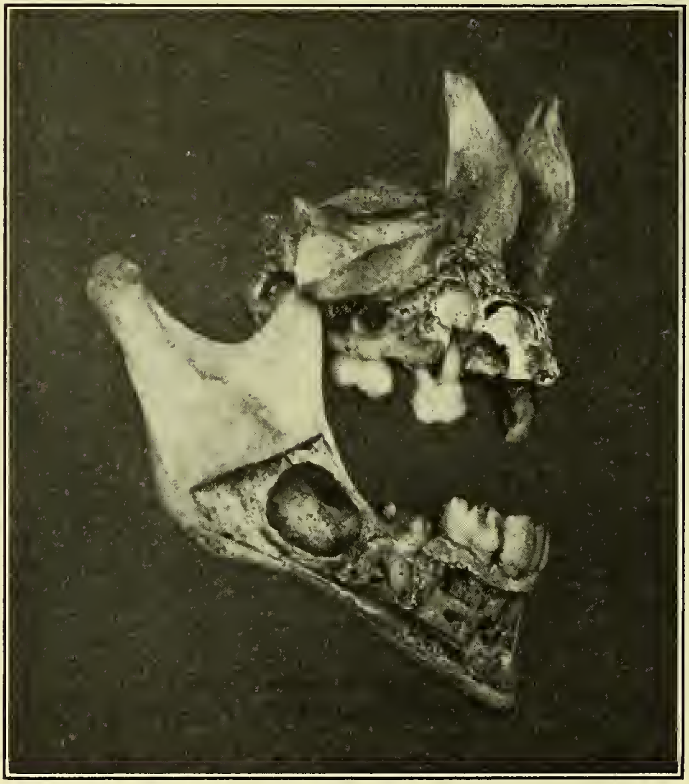


FIG. 27.—Infant maxilla and mandible. Age about twenty-six months.

1. *Pulp Diseases.*—Chronic constructive diseases, viz.: tubular calcification, secondary dentin, pulp nodules, and calcific degeneration are more frequently concerned as causative factors. Acute destructive diseases, viz.: arterial hyperemia, venous hyperemia, inflammation, and suppuration are less frequent causes, though sometimes concerned.

2. *Pericemental Disturbances.*—Viz.: pericementitis, deposits of calculus on the roots, hypercementosis, resorption of roots, malocculsions, all result in pressure on and irritation of the nerves of the pericementum, and reflexes frequently result. Fig. 24.

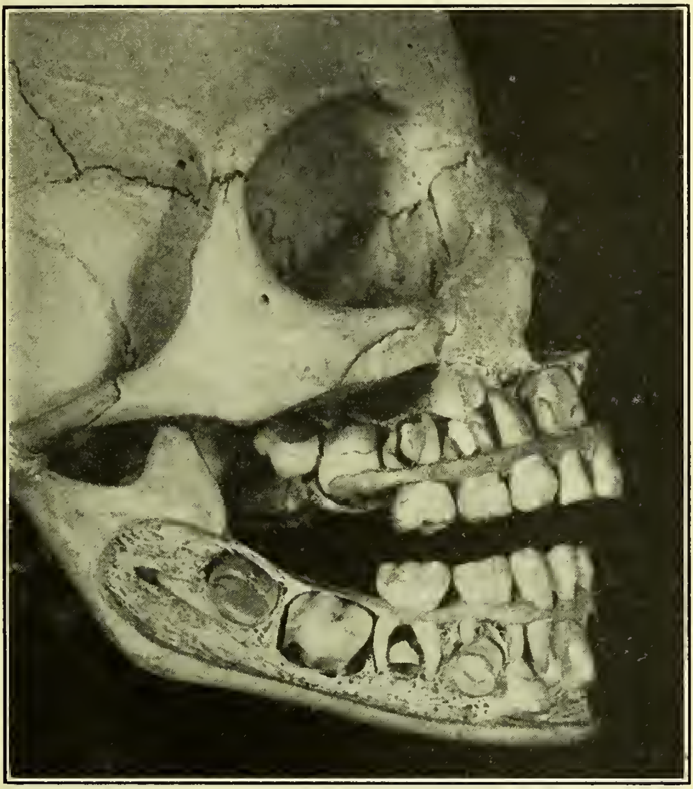


FIG. 28.—Deciduous denture of right side. The forming succedaneous teeth and first and second permanent molars are seen. Age about five years.

3. *Dentition.*—The pressure element is largely concerned here, owing to lack of harmony between gum absorption and pressure of blood supply at the root end, resulting in irritation in the gums, pulp or pericementum of the erupting tooth. It must be remembered that at five years of age fifty-two teeth are in process of development and

absorption, and that reflexes are natural under these circumstances. In the infant the spinal nervous system is more highly developed than the brain, consequently inhibitive nervous control is subordinate to spinal activities and these are likely to be more intense manifestations in the infant than in the adult. Figs. 25 to 37.

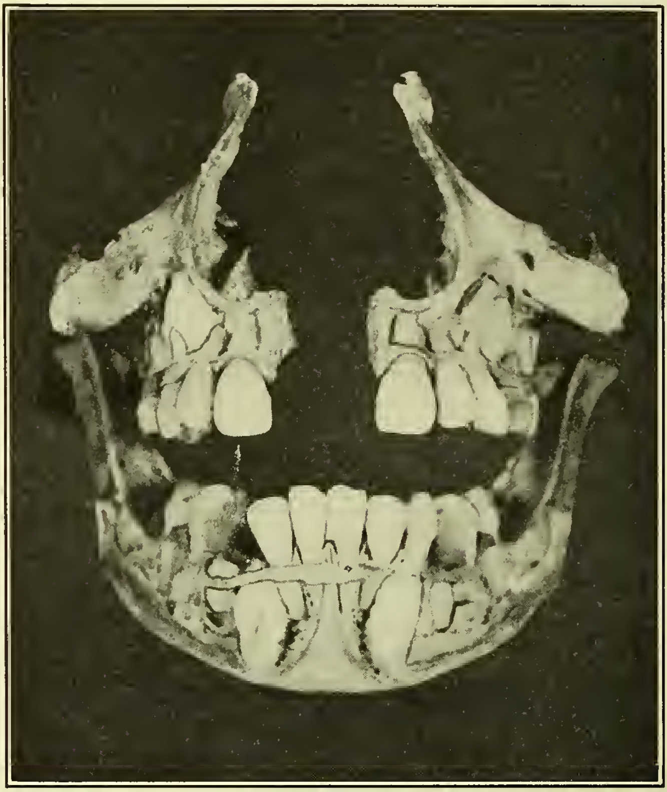


FIG. 29.—Development of the teeth. About the seventh year.

4. *Impacted Teeth.*—Here also pressure is largely concerned, producing resorptions, hypercementosis, pulp and pericemental disturbance in adjoining teeth, as well as reflexes in distant parts. Figs. 38 to 43.

5. *Crowded Arches and Orthodontic Procedures.*—The pressure of crowded teeth and contracted arches, too rapid movements of the teeth, improper fixation, and insufficient anchorages, are likely to result in pulp and pericemental disturbance, leading to distant reflex manifestations. Fig. 44.

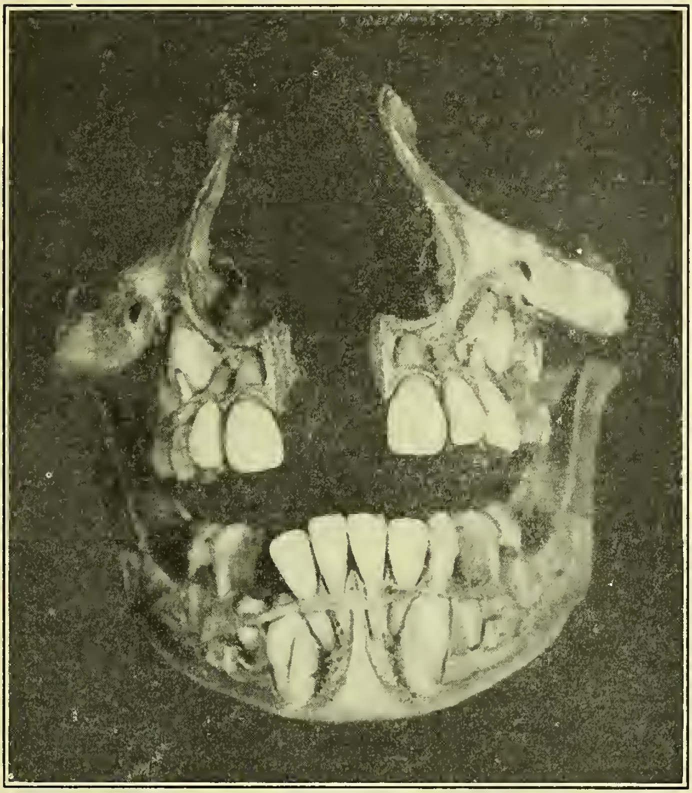


FIG. 30.—Maxilla and mandible about the eighth year.

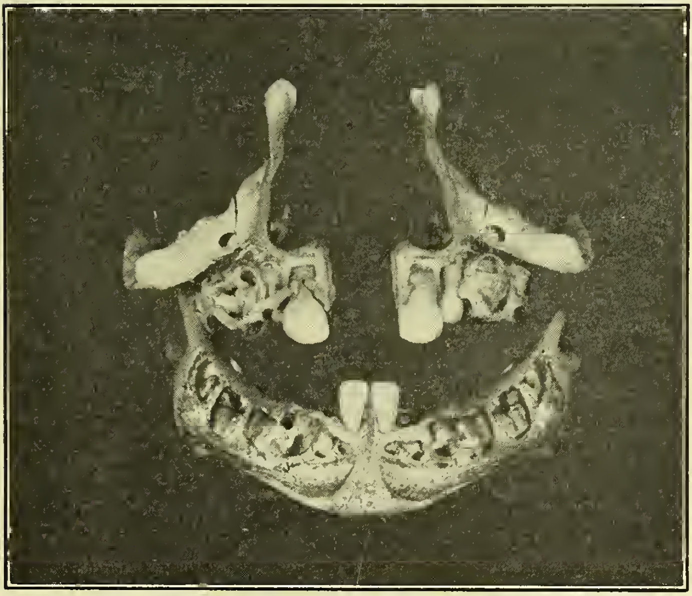


FIG. 31.—Infant maxilla and mandible. Age about eight and one half months.

The character of the disturbance may be either in the form of

1. **Sensory Reflexes,** viz.—Neuralgia, or sensory paralysis, (anesthesia from nerve fatigue).

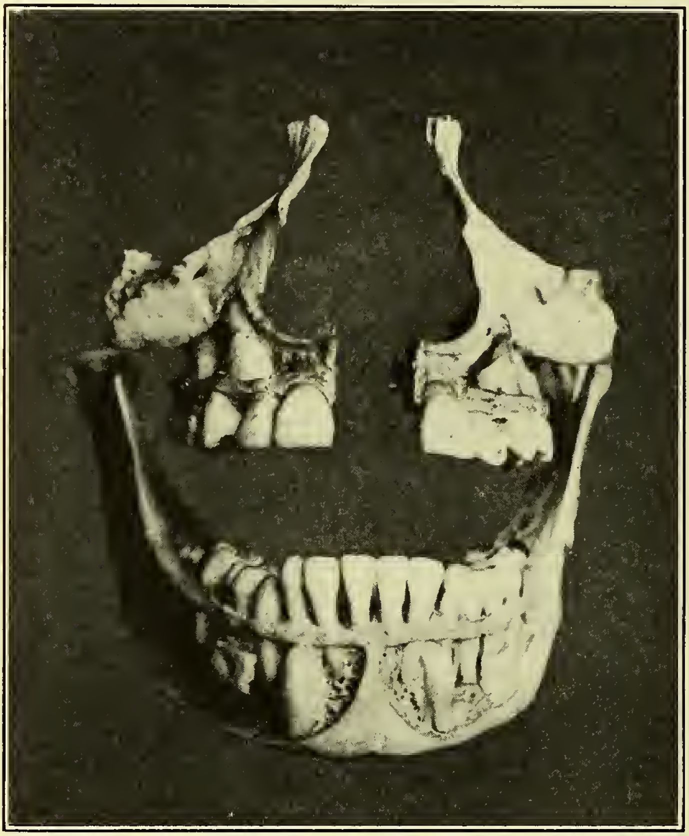


Fig. 32.—Maxilla and mandible. Age about nine years.

2. **Motor Reflexes,** viz.—Increased or diminished excitability of muscular tissue, resulting in contractions or paralysis of groups of muscles, or

3. **Trophic or Nutritive Reflexes.**—Resulting in various nutritive disturbances.

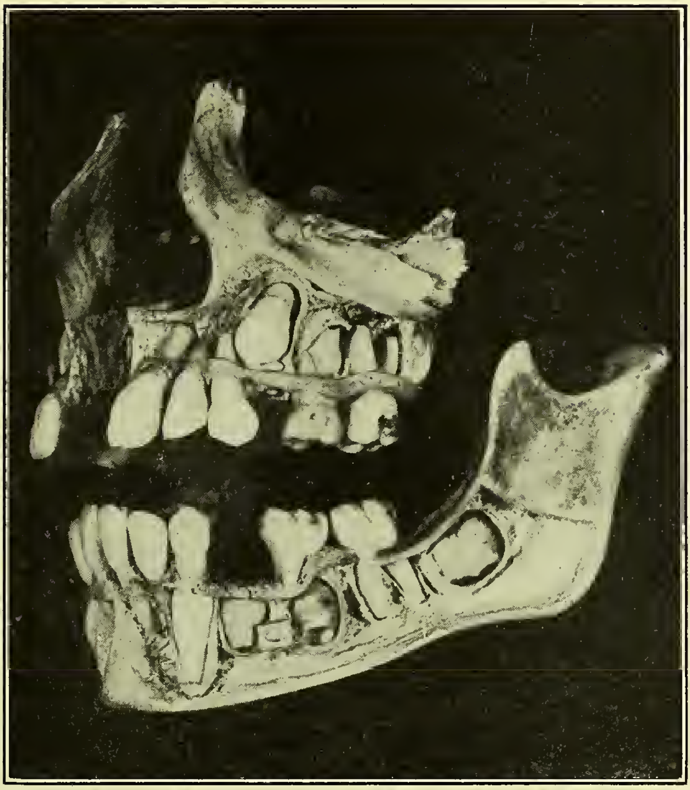


FIG. 33.—Maxilla and mandible, about the tenth year.

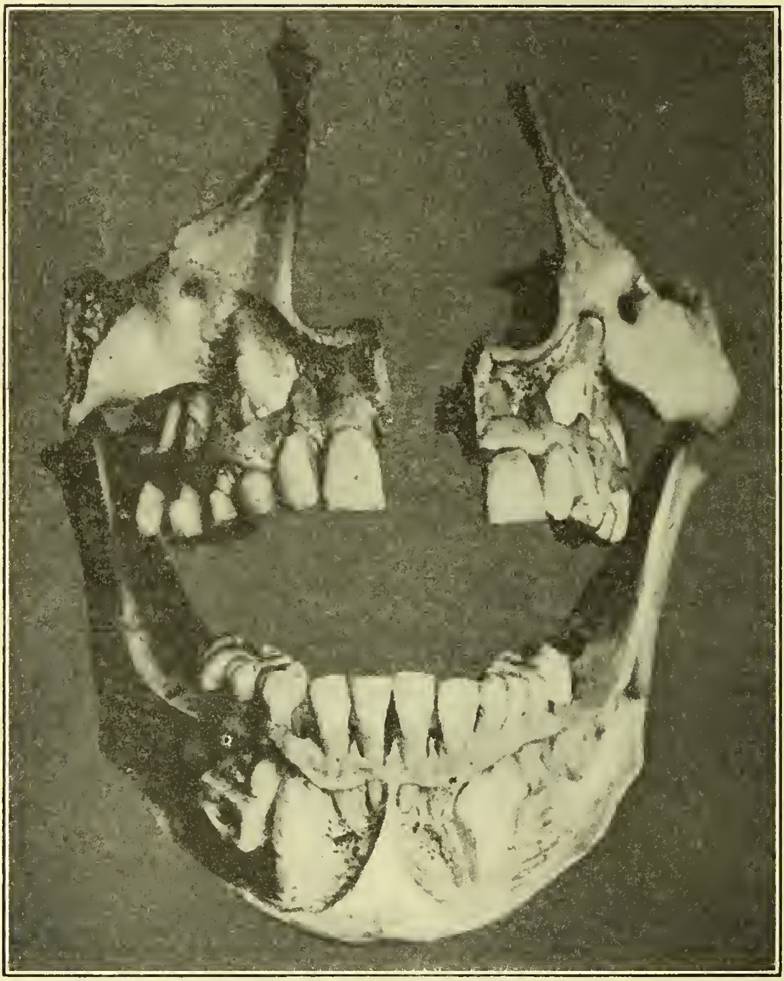


FIG. 34.—Maxilla and mandible. About ten years.

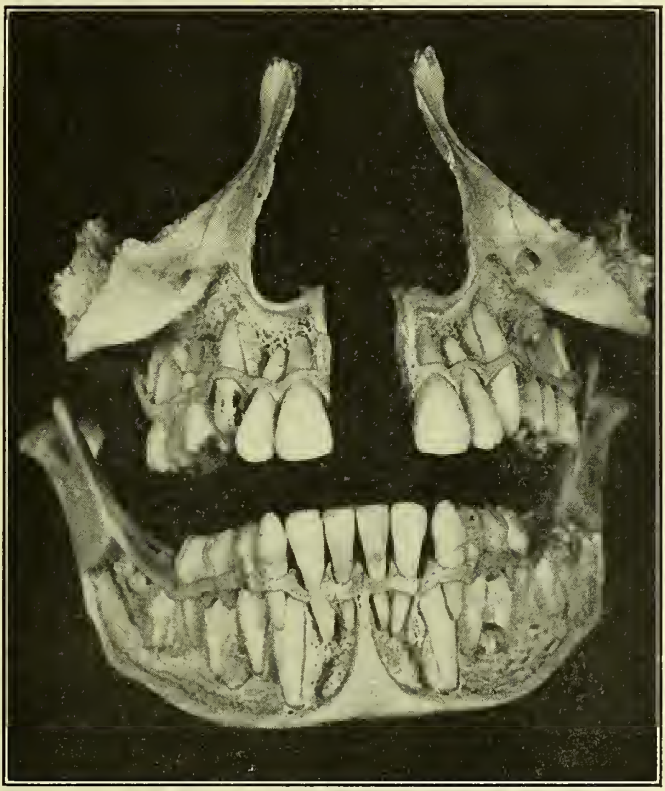


FIG. 35.—Maxilla and mandible at about the twelfth year.

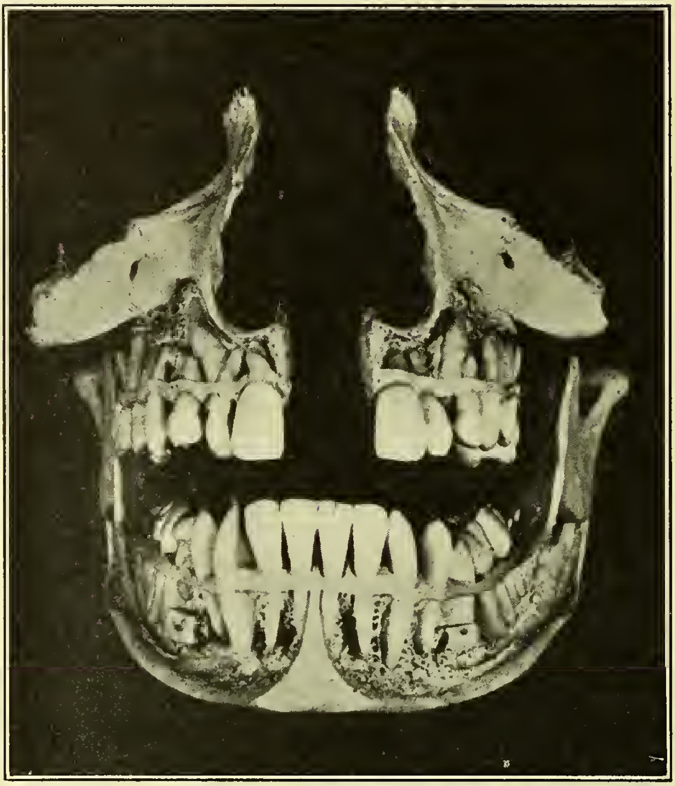


FIG. 36.—Maxilla and mandible about the fourteenth year.

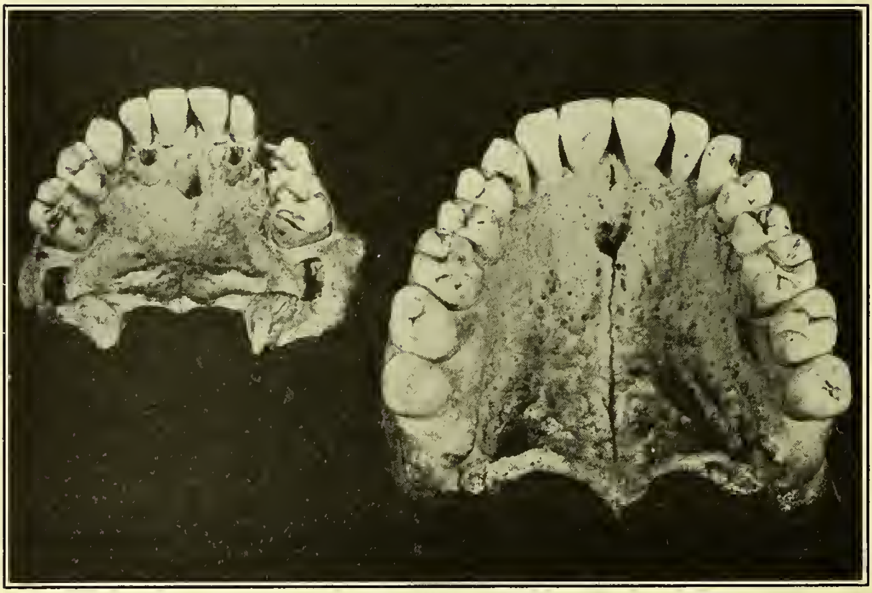


FIG. 37.—Deciduous and permanent dentitions of the upper jaw. The anterior and posterior palatine foramina are also shown.

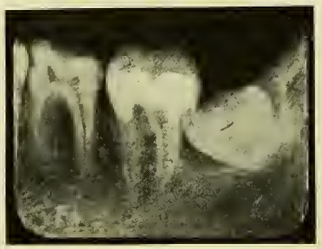


Fig. 38.—Impacted third molar.

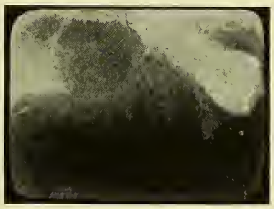


Fig. 39.—Impacted cuspid in supposedly edentulous mouth.

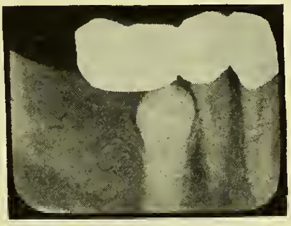


Fig. 40.—Impacted bicuspid, erupting under bridge.

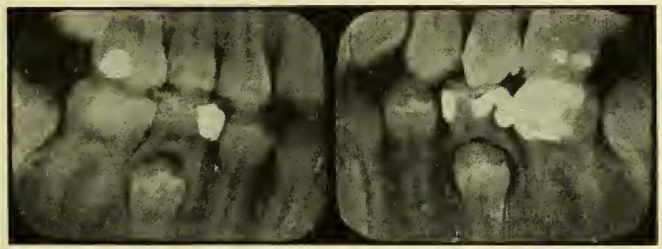


Fig. 41.—Erupting lower second bicuspids and molars, right and left sides, upper second molars also moving into place.

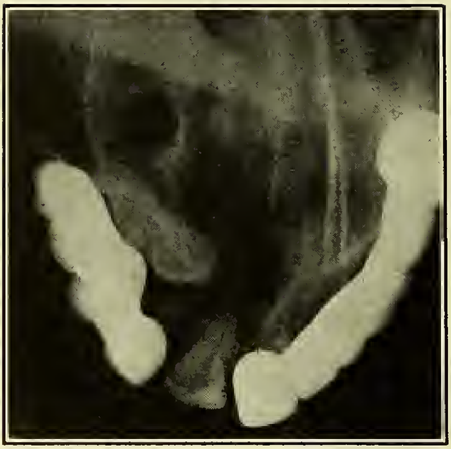


FIG. 42.—Impacted cuspid under bridge.

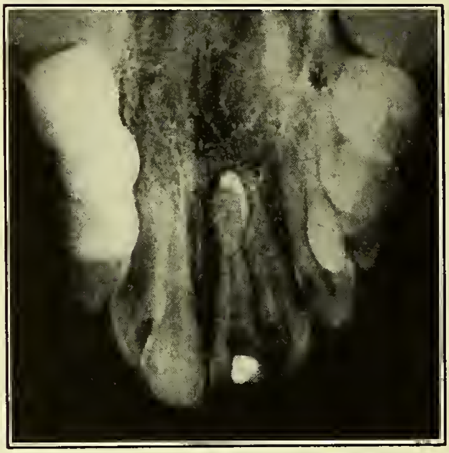


FIG. 43.—Impacted supernumerary incisor.

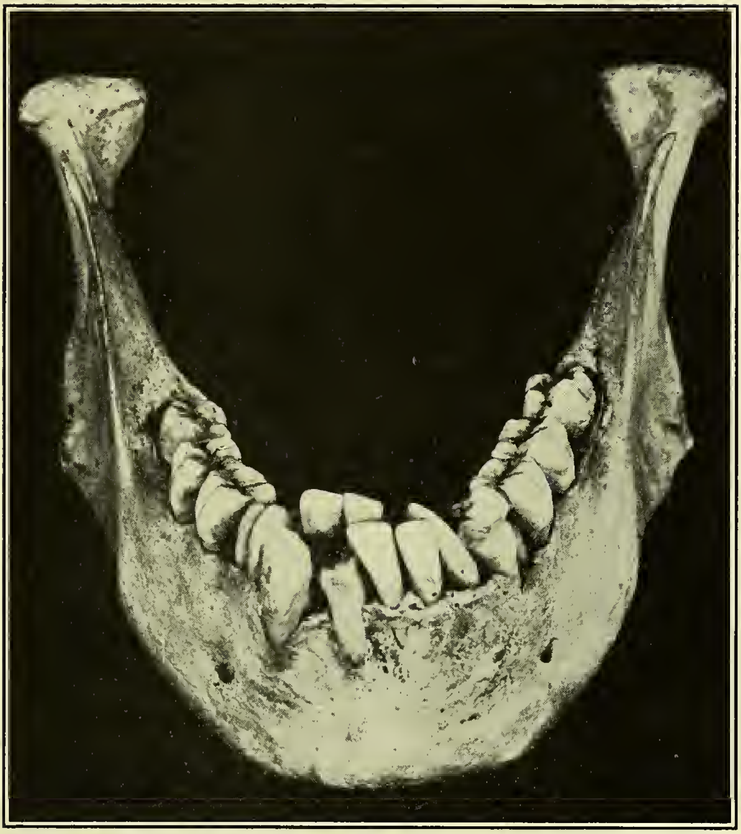


FIG. 44.—Supernumerary teeth, marked irregularity and badly crowded arch.

CHARACTERISTIC REFLEX NEUROSES FROM TOOTH DISTURBANCE

As previously mentioned, the central origin of the fifth nerve is closely associated anatomically with those of the third, fourth, sixth, seventh, ninth and tenth nerves, which readily accounts for the vague and distant manifestations produced. As a result, the following reflex neurotic conditions are seen, which may be mentioned and classified as follows:

1. Disturbances of the Eyes.
2. Disturbances of the Ears.
3. Muscular Disorders.
4. Visceral Disorders.
5. Trophic and Vaso-Motor Disturbances.
6. Affections of the Nerves (neuralgias, tic, paralyses).
7. Affections of the Brain Centers.

1. *Disturbances of the Eyes.*—Functional disturbances predominate. Vasomotor disturbances are in the minority. The eyes are frequently affected with one or the other of the following conditions, viz.: strabismus, ptosis, paresis of the orbicularis, spasm of the ciliary monocular diplopia, paresis of the rectus, partial paralysis of the third nerve, lagopthalmus, copious lachrimation, neuralgia of the eyeball, sclerotitis, conjunctivitis, keratitis, mydriasis, loss of accomodation, glaucoma, ambliopia, and exopthalmos.

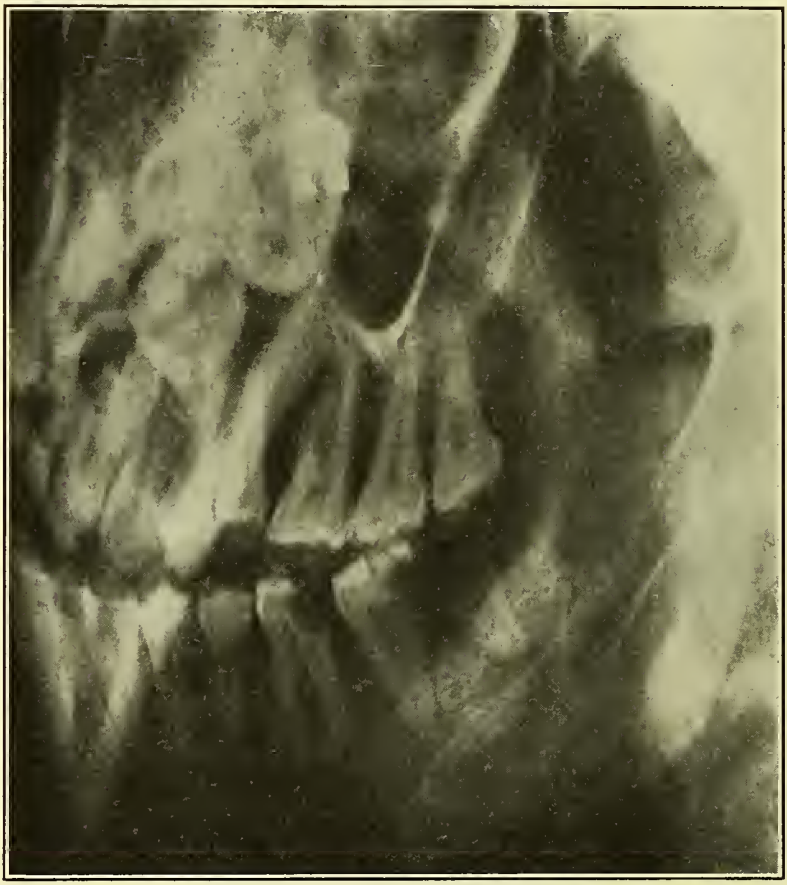


FIG. 45.—Retained third molar roots, causing trismus as result of poor surgical treatment.

2. *Disturbances of the Ears.*—Such conditions as otorrhea, catarrhal and purulent inflammation of the middle ear, otalgia, tinnitus aurium, deafness, reflex pains in the ears are common.

3. *Muscular Disorders.*—Among these may be mentioned facial spasms affecting the facial group of muscles (these may be tonic or

clonic), chorea, trismus, and torticollis. The fifth and seventh nerves are very closely connected in their manifestations. Fig. 45.

4. *Visceral Disorders.*—Such as obstinate vomiting, laryngeal cough, (reflex from teething), aphonia, hiccough, cardiac palpitations, uterine neuralgias.

5. *Trophic and Vaso-motor Disturbances.*—The existence of a trophic centre and trophic nerves is still under dispute. However, among the disturbances of this nature may be mentioned ulceration of the cornea, herpes, (fever blisters), papular and vesicular eruptions on the body and limbs during dentition.

6. *Affections of the nerves* (Neuralgias, Facial tic, tic Douloureux and paralysis).

(*a*) **Neuralgias.**—Among these may be mentioned neuralgias of the face, scalp, eyes, ears, neck, chest, arm, heart, ovarian and uterine neuralgias, and sciatica. It is well to note at this point that the majority of reflex neuralgias arising from the teeth are usually located in some part of the nerve branch supplying the source of irritation. However, they may be and occasionally are reflected to distant parts, (1) either to other branches of the cranial nerve, or (2) to other and adjacent nerves. Pain in the upper teeth is usually reflected to the parts supplied by the superior maxillary division of the fifth nerve; pain in the lower teeth, to the inferior maxillary distribution; while pain in either upper or lower may be referred to the ophthalmic division and the parts supplied by it. Pain referred to the opposite side of the face to that in which the cause is located is extremely rare. The acuteness of the reflex pain has no apparent relation to the extent of the irritation producing it. A small area of exposed dentin on the distal surface of a lower third molar, located near the gingival line, may be the cause of intractable neuralgia. The acuteness of the pain may be governed to quite a degree by the degree of sensitivity inherent in the protoplasm of the affected tissues, and is most common and pronounced in those whose nervous irritability is exalted, viz.: in those individuals classed as neuralgics or neurotics.

The cause is frequently difficult to determine owing to the indefiniteness of location and character. The pain may be intermittent, continuous or periodic and may vary from a sensation of indefinite pressure to an intense, sharp, dull or throbbing character. It is necessary to make careful study of the history and symptoms, together with physical and roentgenographic examination.

(*b*) **Facial Tic.**—A discussion of neuralgias would be incomplete without mention of tic. Facial tic or intense neuralgia of the seventh nerve is mostly located in the zygomatic and orbicularis palpebrarum muscles of one side. It may spread to other groups and affect the tongue, neck, shoulder and arm. It may be considered a true reflex.

(*c*) **Tic Douloureux** (Trigeminal Neuralgia).—The cause and pathology of this condition is unknown. It is supposedly not due to pathologic conditions of the teeth. Regardless of this, many patients suffering from the condition insist on having tooth after tooth extracted until finally all may be lost without relief of the pain. Usually it is confined to middle aged and old persons. In the beginning, the pain is of a sharp, shooting, darting, stabbing character, very intense or excruciating, located in the area supplied by either branch of the fifth nerve. After a few months or years, it becomes more and more frequent and of longer duration, lasting from five to sixty seconds and in rare instances to five or more minutes. There is frequently a characteristic alteration of expression, or stare to the face, and on questioning, it may be found that the patient will give a history of a premonitory aura, similar to that seen in epileptics. Slight pressure, or drafts of air may bring on an attack, or it may start without apparent cause. It is the most severe of the various forms of neuralgia and may be temporarily relieved by alcohol injection or permanently cured by nerve resection.

(*d*) **Paralysis** in the form of facial paralysis, paralysis of the arm, hemiplegia, paraplegia, general paralysis and infantile paralysis are all mentioned by various authorities as resulting from tooth disturbance.

7. *Affections of the Brain Centres.*—Convulsions (clonic and tonic), headaches, hysteria, chorea, mental backwardness, imbecility, dementia precox, epilepsy and insanity (maniacal and melancholic) all may occasionally be resultant of reflexes about the teeth.

Bibliography

McGehee, W. H. O.: Diagnosis of disturbances of the oral cavity, Dental Cosmos, Nov. 1926, p. 1033.
McGehee, W. H. O.: Reflex disturbances and their relation to modern dental practice, Dental Summary, July 1920, p. 583.
Tyson, James: "Physical Diagnosis," Blakiston, 1901.
Brooks, Herbert Thomas: "Diagnostic Methods," 3rd ed., C. V. Mosby Co., St. Louis, 1918.
Simon, Chas. E.: "Clinical Diagnosis," 3rd ed., Lea and Febiger, Philadelphia, 1900.
DeGarmo, Charles: "Essentials of Method," Heath & Co., Boston, 1909.
Thoma, K. H.: "Oral Roentgenology," 2nd ed., Lea & Febiger, Philadelphia, 1922.
Labat, Gaston: Neuralgia of the trigeminal nerve, Dental Cosmos, Oct. 1929, p. 980.
McGehee, W. H. O.: Physical diagnosis, Dental Summary, March 1909.
McGehee, W. H. O.: Oral manifestations of constitutional disturbance, American Dentist, Aug. 1915.

Darlington, Chas. G.: Pathological laboratory examination for the dentist, Jour. Laboratory and Clinical Medicine, vol. XIII, no. 4, Jan. 1928, p. 376.

Epstein, Irwin A.: Blood examination in the practice of dentistry, Jour. Amer. Dent. Assoc., Oct. 1929, p. 1808.

Simpson, C. O.: Value of the roentgen-ray in oral diagnosis, Jour. Amer. Dent. Assoc., Nov. 1927, p. 2025.

Best, Elmer S.: Examination and case records, Jour. Amer. Dent. Assoc., May 1927, p. 890.

Cushman, Frank: Oral diagnosis as a first approach to preventive dentistry, Jour. Amer. Dent. Assoc., Dec. 1929, p. 2251.

Box, Harold K.: Evolution of periodontal pus pocket, Canadian Dental Research Foundation Bulletin, May 1921.

McGehee, W. H. O.: Basal principles involved in the science and art of diagnosis, Temple Dental Review, March, 1934, p. 10.

McGehee, W. H. O.: Foundation stones in building a logical course in oral diagnosis, Trans. Amer. Asso. Dental Schools, 1934, p. 314.

McGehee, W. H. O.: Mr. Sherlock Holmes in dentistry, The Apollonian, Oct., 1934, p. 247.

CHAPTER II

ROUTINE METHODS OF DIAGNOSIS

In many instances it will not be necessary to adopt all of the extensive diagnostic measures described in the preceding chapter. Acquirement of some of the information, as outlined, may be deemed desirable, while other parts of it may be considered unnecessary. The scope of the procedures adopted will vary for each case and be regulated by the judgment and experience of the dentist, the type of patient applying, the character and scope of the practice being conducted and other considerations.

For ordinary cases the following routine procedures, now to be described should be followed, viz.: I. General Physical Inspection; II. Examination of the Soft Tissues; III. Examination of the Hard Tissues; IV. Examination of the Pulp and Peridental Tissues.

I. General Physical Inspection.—Much of this information may be obtained by casual observation on the reception of, or while the patient is being placed in the chair. Note the general appearance and state of health, age, sex, build, gait or carriage, temperature, presence or absence of eruptions, complexion, color of the hair, eyes, lips, and nails, probable state of nutrition, expression of the face, whether animated, placid or apathetic. The patient should be questioned as to the reasons for the visit and the presence or absence of pain, at the same time noting the manner of speech. This will enable the dentist to determine the probable extent and methods of examination necessary. If deemed advisable, the pulse may be taken, which will indicate the probable condition of the circulation. The temperature may also be taken at this time, if fever from any source is suspected. The examiner should be supplied with a number of fine pointed cavity explorers with suitable angles to reach into all localities. Graffrath's number 0, 1, 2, 12, 13 and S. S. White's numbers 2, 3, 6, 11, 12, 17 are good selections. Figs. 46 and 47. These should be kept sharp (36 B. and S. gauge), since they easily become dull or are broken. A pair of silver probes, for exploring fistulous openings and peridental membrane pockets should also be included. Fig. 48. These, together with cheek and lip retractors and tongue depressors, mouth mirrors (plain and magnifying), dressing pliers, floss silk, compressed air or the chip blower, cotton rolls, mouth napkins, cottonoid and other absorbents, cotton roll clamps, electric mouth lamps, magnifying glasses (either hand or binocular loupes), saliva ejector and rapid separators should be made available for immediate use by the assistant, before beginning the examination. Fig. 49. Five percent alcohol or an antiseptic solution should be available for spraying the mouth before and during the examination, and 50% alcohol for swabbing individual teeth, where special inspection is necessary, should also be at hand, ready for use.

Avoid placing the fingers in the mouth of the patient in so far as possible, for this procedure is unpleasant to the patient and, in cases of infectious or specific nature, may be dangerous for the operator. In these latter cases, rubber gloves should be used and special care in sterilization should be given all instruments and accessories. The hands of the operator should be thoroughly cleansed and sterilized before and after all examinations or operative work. Instruments should be given the same attention.

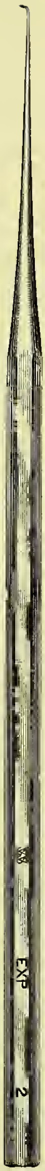


FIG. 46.—Cavity explorer.

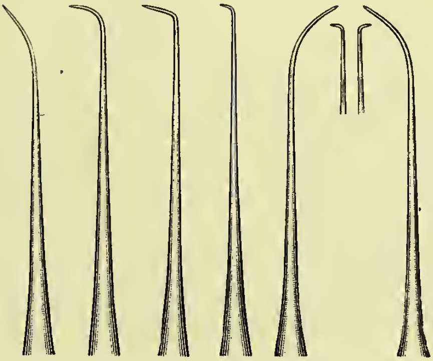


FIG. 47.—Cavity explorers.

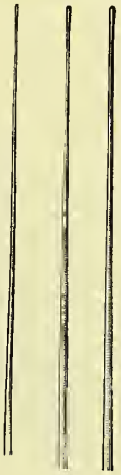


FIG. 48.—Silver probes for diagnosing pericemental pockets and abscess sinuses.

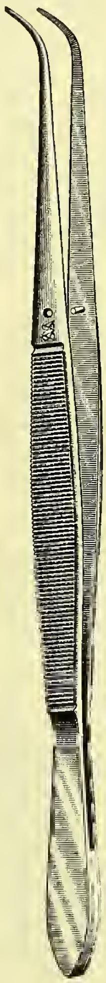


FIG. 49.—Dressing pliers.

II. Examination of the Soft Tissues.—Swellings and changes in the contour of the face, if present, should be noted, after which the presence or absence of cyanosis, anemia, herpes or fissures of the lips should be recorded. Observe the color and contour of the mucus membranes of the lips, cheeks, palate, sublingual and submaxillary regions and gingiva, noting the presence of growths, tumors, leukoplakia or evidences of specific infections. The gingivae should receive careful attention, looking for fistulous openings, disturbances in the interproximal spaces, recessions or hypertrophies and the presence of pockets

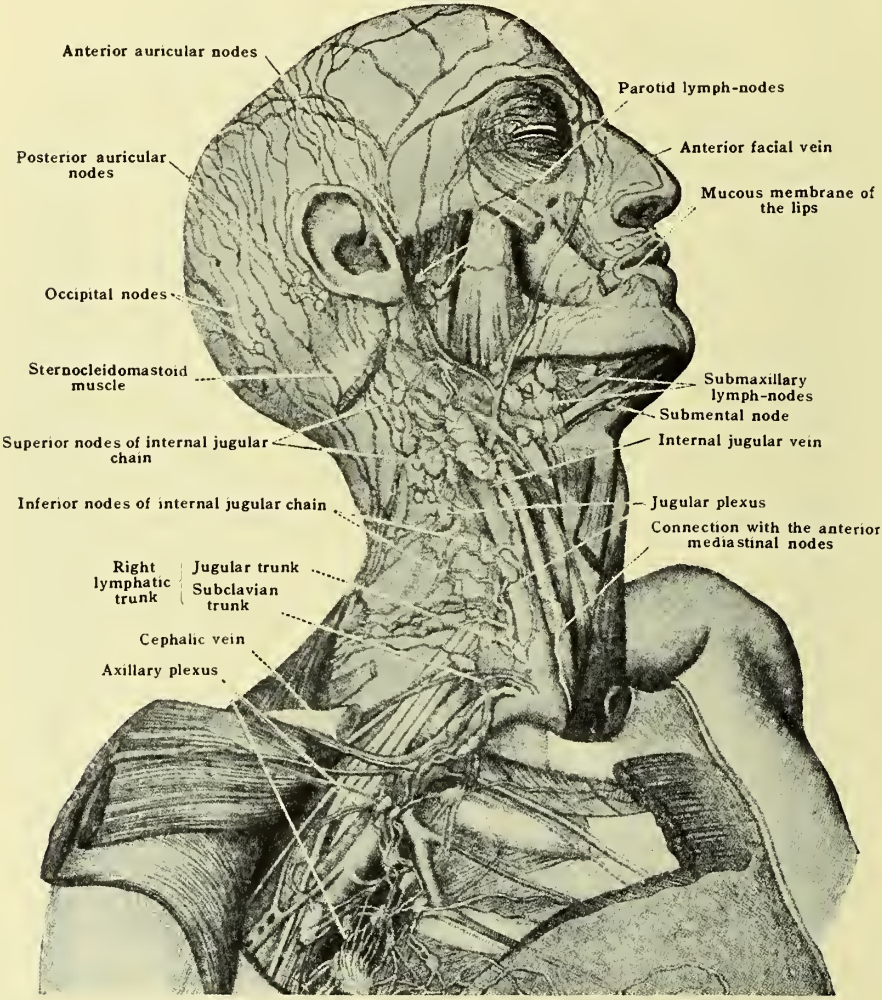


FIG. 50.—Lymphatics of the head and neck. (Morris, after Toldt.)

and periodontal affections. Palpation over the roots of the teeth may reveal tenderness (indicating inflammatory disturbance), or perforation of the maxilla from septic disturbances. Observe the condition of the tongue, whether coated or furred, and note the condition of the tonsils, uvula and posterior fauces, looking for adenoids and tonsillar inflammations and infections. It is well to investigate the lymph

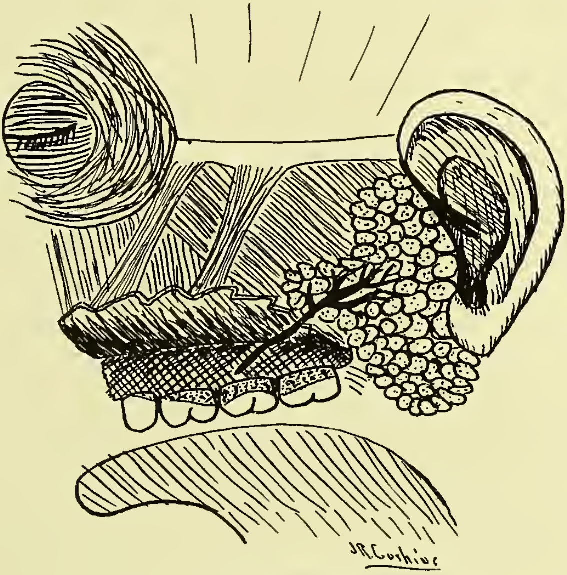


FIG. 51.—Parotid gland and duct.

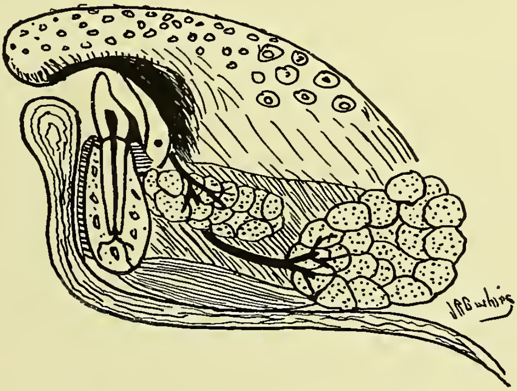


FIG. 52.—Sublingual and submaxillary glands.

glands at this time, if infections are suspected, palpating the submaxillary, sub-mental and cervical regions. Fig. 50. If they are normal, they are not palpable. If acutely inflamed, they appear soft and tender, while they become hard and easily felt in chronic disturbances. Inspect the ducts of the salivary glands (Figs. 51 and 52) for possible occlusion and ranula, and note the condition of the oral fluids, whether free-flowing and watery, diminished in amount, or mucinous and gelatinous.

Halitosis.—Offensive breath should be noted and its cause sought. It may be due to unhygienic conditions in the mouth, depositions of fermenting and putrefying food debris, caries, deposits on the teeth, putrefactive decomposition of the pulp, remnants of roots, periodontoclasia, ill fitting crowns and bridges, infected tonsils or adenoids. It may also be caused by septic disturbances in the nasal passages, pharynx, larynx or lungs. Gastric ulcer and carcinoma of the stomach are additional causes to be borne in mind, these latter often being accompanied by a fetid odor. Constipation and the absorption of the products of putrefaction and decomposition from the gastro-intestinal tract are also frequent causes. Diabetes is often accompanied by a sweetish odor resembling that of honey, sweet apples or hay, and uremia may present a decided ammoniacal odor of urine on the breath. Pregnant or menstruating women present characteristic breath odors during these periods. Chronic alcoholics often present a foul odor (not necessarily alcoholic) of the breath and saliva. Patients suffering from nephritis, epilepsy or dementia, also present foul, characteristic breath odors. Certain chemical and medicinal substances produce distinctive odors.

Characteristic food odors are familiar to all, such as the persistent ones resulting from onion and garlic eating. Such foods as cabbage, celery, oranges and bananas produce mild odors, disappearing in an hour or two. The odor of coffee may be detected for an hour or two after drinking. Smokers will exhibit the odor of tobacco for ten to twelve hours after use. Many of these odors are due to either retention of the food or drug in the oral cavity, to absorption and elimination via the lungs and nasal passages, or to absorption from the blood into the saliva during metabolism.

The uncontaminated breath is nearly odorless in health, being, however, mixed with a slightly sweetish odor, originating supposedly from mucous glands located at the muco-cutaneous junction in the anterior nares. Doctor Henry C. Ferris[1] states that "The dentist in his daily practice can make differential diagnoses between caries, putrescent pulps or periodontoclasia from the fetor of the breath; and in rare cases, carcinoma of the tongue and tuberculous ulcer or necrosis of the soft tissue, as in noma. The odor of the breath is a combination of several odors, but the residual mouth odors are most accurately distinguished from the filtered saliva. This we must acknowledge, and any technic which simplifies the recognition of residual odors is worthy of consideration. The education of the olfactory sensations can be developed only by constant observation; and the practitioner who has developed a differential sense of smell has broadened his diagnostic ability." The dentist should be particularly careful about his own breath and should take every precaution to seek the cause and eliminate disagreeable breath and body odors for obvious reasons.

III. Examination of the Hard Tissues.—The careful inspection of the teeth should now receive due consideration. The surfaces of the teeth should be examined first. Their general appearance from a standpoint of cleanliness should be observed, extent and character of deposits, color, shape and size, type of occlusion, shape of the arches, presence of irregularities or malformations, or absence of teeth from the arch should be noted. Teeth in traumatic occlusion should be observed and recorded. A thorough and systematic examination should now be made for the minutest defects. This should usually be preceded by prophylactic cleansing, except in well cared for mouths, or where special circumstances do not permit. Regions requiring special attention are (1) pits and fissures, (2) the gingival third region, (3) proximal surfaces and (4) the margins of fillings, crowns and under fixed bridges.

The appliances to be used in making the examination have previously been mentioned. The use of the electric mouth lamp, transilluminator, and X-ray will be valuable adjuncts in detecting proximal caries, decay under fillings, overhanging gingival margins on fillings and crowns. The following classification of dental caries into stages (after Burchard-Inglis[2]) will be valuable in determining and recording the depth or extent of caries of the enamel and dentin.

CLASSIFICATION OF DENTAL CARIES

1. Superficial caries. The surface of the enamel is affected.
2. Simple caries. Penetration to the dento-enamel junction.
3. Deep seated caries. The inter-globular spaces have been involved, with a cavity of considerable depth.

4. Caries with almost exposed pulp. Usually a large, well defined cavity.

5. Caries with pulp involvement.

6. Caries with perforation laterally or through the floor of the pulp chamber.

7. Loss of the crown of the tooth from caries.

8. Caries of the remaining root.

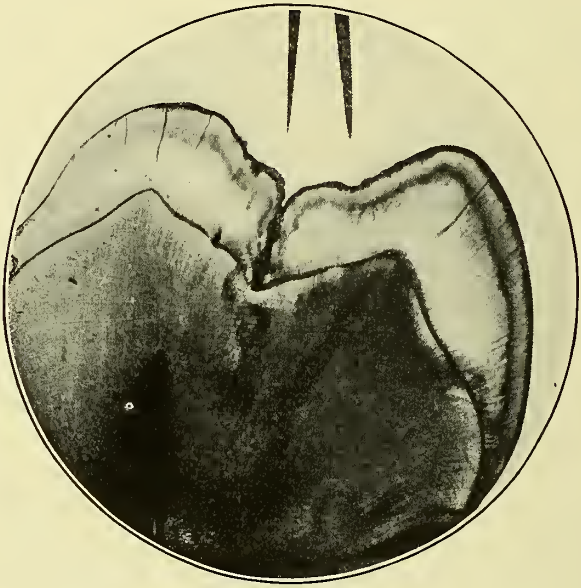
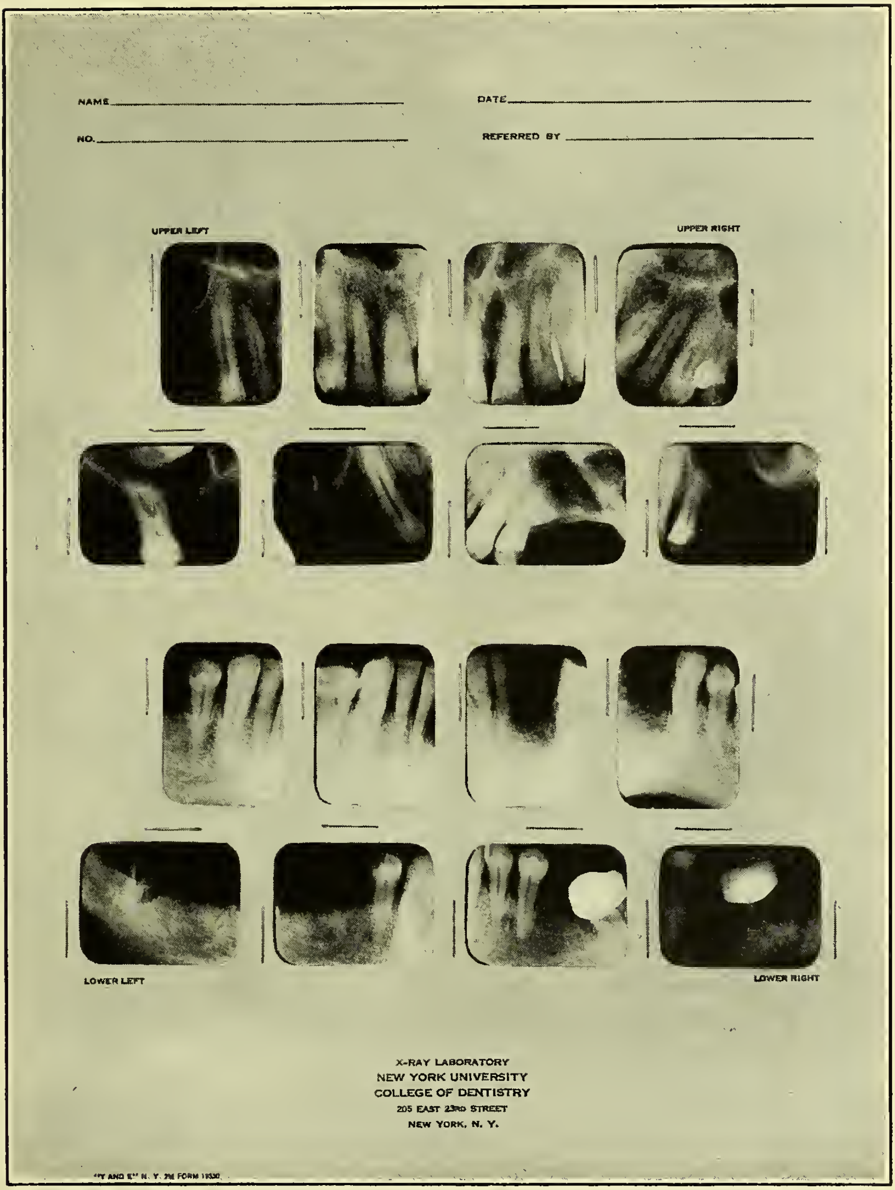


FIG. 53.—Explorers in relation to an occlusal fissure. (Courtesy of Dr. C. F. Bödecker.)

All findings made during the examination should be recorded on a suitable chart which can be conveniently referred to at each visit of the patient and which should finally become a part of the permanent record of the office. Special care should be observed in the examination of pits and fissures, located at the junction of the developmental lobes of the teeth. Although not decayed, they may contain or be surrounded by defective enamel structure which should receive attention as a preventive measure (prophylactic odontotomy). Fig. 53. A more detailed technic for detection of defective structure in these localities is described in Chapter VI in connection with the discussion of the operation of Prophylactic Odontotomy.

A routine systematic procedure should be followed in making the examination, which should always begin at a definite locality and follow a regular course to its termination. The dentist may determine his own method, but the following is herewith advocated.



NAME

DATE

NO.

REFERRED BY

X-RAY LABORATORY
NEW YORK UNIVERSITY
COLLEGE OF DENTISTRY
205 EAST 23RD STREET
NEW YORK, N. Y.

FIG. 54.—Sixteen film roentgenogram mount. Two views of each tooth are obtained.

1. *Lower Teeth.*—Start at the third molar on the left side and examine the buccal or labial, occlusal and lingual surfaces, in the order mentioned,

of each tooth separately, coming forward to the median line. Repeat the procedure on the right side. Then examine the proximal surfaces in the same order.

2. *Upper Teeth.*—Follow the same course as for the lower arch.

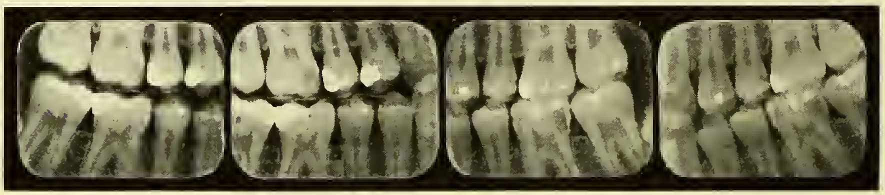


FIG. 55.—Bite wing films.

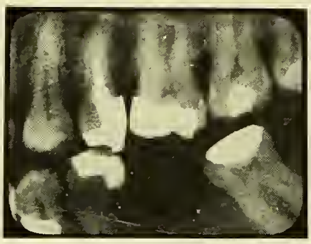


FIG. 56.—Overhanging fillings on bicuspids.

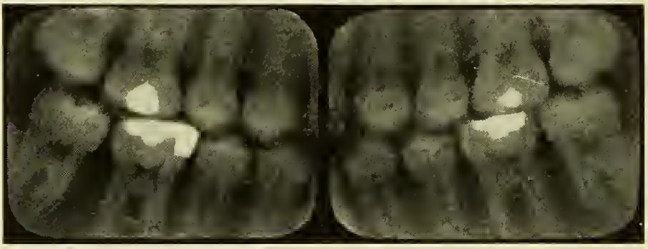


FIG. 57.—Caries on distal surface of lower right and left second bicuspids. Artefact on mesial surface upper right first bicuspid. Four fillings in good condition.

As each condition is found, it should be recorded on the examination chart. In case of doubt, a question mark may be made on the chart in the indicated locality, which may be further investigated at a later period of the examination. Great care should be observed in examining proximal surfaces. Explorers, using the numbers previously mentioned, and the passage of floss silk will aid. Fraying of the floss will indicate the possible presence of calculus, a sharp cavity margin, or a defective filling. However, too much dependence should not be placed in this latter test, since the fraying of the floss may not occur and a more careful examination later reveal a condition needing attention. Contact points should be thoroughly tested with the floss, noting their location, type and size, as well as condition as to proper "knuckling." Slight separations or open contacts, due to improper contact points, should be recorded and later remedied to prevent food impactions. In cases of doubt as to the presence of caries, the rapid separator may be placed in position and the teeth carefully drawn apart to afford a better view. Dryness of tooth surfaces is also essential in many instances. The use of the saliva ejector and absorbents to exclude moisture, the swabbing of the tooth with alcohol, 50% solution, subsequent drying with pledgets of absorbent cotton, and the utilization of transillumination from a well constructed electric mouth lamp will be valuable in many cases. Magnifying glasses, either hand or binocular, should also frequently be resorted to. No examination should be considered complete without a full series of radiograms. Fig. 54. The use of bite-wing films (see Figs. 55, 56 and 57) for detecting caries and other surface defects is a valuable and time saving procedure, where for any reason radiograms of the roots, apical tissues and surrounding bone, are not deemed necessary.

ODONTALGIA

Patients will frequently apply for the relief of pain. Under these circumstances, the routine examination should be deferred and effort at once made to locate, determine the source, and relieve the suffering of the patient. Pain is usually due to stimulation or excitation of the sensory nerves from physical or chemical injury, or occasionally to pathologic changes in the central nervous system. Pain is one of the early manifestations of disease and may be interpreted as a protective device on the part of nature to warn us of the presence of some pathologic disturbance. The intensity of pain varies in different individuals, and in different parts of the body; race, age, sex, locality, density of tissue, nerve and general health conditions being factors regulating its variability. The degree of pain is not always in proportion to the gravity of a disease.

Pain may be described as boring, pungent, darting, lancinating, shooting, lightening, jumping, tearing, grinding, throbbing, sharp, intermittent, continuous, periodical, lacerating, acute, aching, referred or reflex, depending on its cause and character. Pain in and about the teeth may usually be due to exposed dentin, pulp or pericemental disturbance, or diseases of the gingival or underlying bony tissues, though it may be referred from distant sites. The pain of pericemental disturbance is often located definitely in the affected tooth, since the pericementum is the tactile organ, while pulp disturbance usually manifests itself in pain of an indefinitely located or reflex character, the pulp having no sense of location, not being supplied with tactile nerves. For this reason, location of the seat of pain in pulp disturbances is frequently difficult to determine and the patient's testimony is very misleading. Occasionally it may be attributed to a definite locality, when examination may reveal its origin from an entirely different source, it being difficult to persuade the patient of the error. In other cases it may be expressed as an indefinite neuralgia or referred to the opposite jaw, to any of the teeth on the same side of the mouth or to tissues supplied by another branch of the fifth (trigeminal) nerve. The extensive distribution of this nerve and its close connection with other nerves should constantly be borne in mind, thus accounting for pains referred to the eye, ear, nose, temple, forehead, occipital region, the sinuses of the face or to far distant points.

The character of the pain is frequently pathognomonic. Intermittent or periodic pain may be initiated by changes of temperature in the mouth from food or drink, touching a sensitive locality, mastication, or motion of the mandible. Throbbing or pulsating pain usually denotes acute inflammation, while lancinating pain frequently indicates neuritis. A feeling of continuous fullness in the tooth often is characteristic of venous congestion (passive hyperemia). Palpation will sometimes reveal the seat of pain in the gingival or other soft tissues of the oral cavity, while tenderness on percussion, looseness of the tooth or slight elongation will indicate its seat in the peridental membrane or periapical tissues. A history of the case is important. The presence of a concealed cavity of decay will sometimes lead to diagnosis of pulp disturbances, although pulp pain may be present in the absence of decay.

IV. Examination of the Pulp and Peridental Tissues.—Following the examination of the surfaces of the teeth, the condition of the pulp, pericementum and periapical tissues must receive attention. Determination of the condition of these parts is made through a consideration of the objective and subjective symptoms, by palpation and percussion, the application of the temperature test, transillumination, use of the mild electric current and by means of the X-ray.

The clinical manifestations of pulp disturbance are largely due to pathologic changes taking place in the vessels and vaso-motor and sensory nerves of the part. As a result of the action of irritants transmitted by way of the dentinal fibrillae, the vaso-motor nerves supplying the vessel walls are first stimulated, then overstimulated and finally paralyzed. The same conditions result in the sensory nerves, with the result that in the early stages of pulp disturbance, arterial and venous *hyperemia* (congestion) occurs from the loss of tone in the vaso-motor nerves supplying the vessel walls. The resultant dilatation of these walls produces lateral pressure on the sensory nerves immediately adjacent, with the production of pain. As the condition increases in degree, stagnation of the blood currents results from pressure on the afferent and efferent blood vessels passing through the apical formen (jugulation). At the same time, progressive, degenerative changes are occurring in the nerves of the part, with increased tendency to dilatation, loss of tone and rupture of the vessels, following which the condition of *inflammation* is fully established. This condition, long continued, finally produces complete paralysis of both sensory and vaso-motor nerves, with ultimate *death of the pulp*, gangrene from loss of the functional activities of its vascular and nerve supply.

If *suppurative* or putrefactive changes occur, the pressure of the gases being formed in conditions of this nature is also productive of pain, so long as any vitality remains in the sensory nerves of the pulp. It may thus be seen that the *pressure element* is largely concerned in the production of the painful sensations manifested in diseases of the organ.

The terminal nerves of the pulp are not supplied with tactile endings, hence the organ has no sense of location. One of the chief characteristics of pulp disturbance is pain of a reflex nature—indefinitely located pain, referred to an adjoining tooth or to distant parts.

The character and extent of the pain exhibited greatly assists in making a diagnosis of the pathologic disturbance present. Pulps are peculiarly susceptible to changes of temperature, since, as is well known, the application of cold produces contraction, while heat causes expansion of tissues richly endowed with a blood supply. The temperature tests (thermal tests) of G. V. Black and Louis Jack, devised years ago, are still of great value in making a diagnosis of pulp disturbance.

TESTS FOR PULP VITALITY

None of the tests for vitality of the pulp are absolutely infallible. The only sure test is entrance into the pulp chamber and direct contact with the contents of the chamber and canals. However, the procedures herewith given will be of assistance in making a diagnosis.

First.—Transillumination of the tooth by means of an electric mouth lamp. A vital tooth will appear translucent and the area surrounding it pink, while a nonvital one will be opaque and often clouded to a gray or bluish-black color. Discoloration and darkening of the tooth are characteristic of non-vital teeth, although in many instances these phenomena are absent. Transillumination in a dark room by means of the denta-lamp will also be of assistance in revealing the condition of the gums and underlying bone, presence of serumal (subgingival) calculus, granuloma and pathologic disturbance of the antrum, frontal sinuses and mastoid bone.

Second.—Prolonged application of iced water or ethyl chlorid will elicit no response from a non-vital tooth.

Third.—Application of a hot burnisher, or hot guttapercha, or hot water will be negative as far as pain production is concerned in non-vital pulps.

Fourth.—Application of the mild electric current will produce a response from a vital pulp, while none will be obtained in non-vital cases.

ELECTRIC PULP TESTING APPARATUS

Numerous types of electric pulp-testing apparatus may now be obtained for this purpose. In using the modern types of vitali-tester, the electrodes are placed in contact with the suspected tooth. The current is now turned on and gradually increased in amount. A dead tooth will not respond to the strongest current of which the machine is capable, while a vital tooth will respond with varying degrees of intensity, depending on the susceptibility of the individual and the state of health of the pulp tested, the teeth of some patients responding more readily than others, and diseased vital pulps responding more or less readily, depending on the pathologic condition present.

In testing vital pulps for the presence or absence of pathologic disturbances, the following procedures may be followed: Apply the current to several known vital teeth, until a tingling sensation is felt, but not until pain is produced. The average current necessary to produce this sensation is termed the *irritation point.* After having established on the machine the irritation point of the patient, it is now a simple matter to distinguish diseased from normal pulp reactions. The following reactions will be of value in determining the probable condition present.

First.—A normal pulp will respond to the current at the irritation point.

Second.—An irritated pulp will respond to the current at or just below the irritation point.

Third.—An inflamed pulp will respond below the irritation point, the greater the degree of inflammation present, the more ready the response.

Fourth.—A suppurative pulp will respond above the irritation point, the more severe the suppurative condition, the less ready the response.

Fifth.—A devital pulp will give no response whatever to the full strength of the current.

Methods of diagnosing pulp, pericemental and periapical disturbances are further considered under Special Methods of Diagnosis and more fully discussed in the chapters on Diseases of the Pulp, to which the reader is referred.

Periodic Examination.—Examination of the mouth should be made for all patients at regular intervals, the frequency to be determined by the age, habits of oral cleanliness and tendency to pathologic disturbance. The majority of children under ten years of age should receive an examination every three months; most persons between ten and twenty years of age twice or three times a year; and patients over twenty at least twice a year. Those patients suffering with periodontal disturbances or who are particularly susceptible to oral disease should receive more frequent attention. Pregnant women should have frequent periodical examinations, which should include inquiry as to the diet and mode of living, as well as routine examination of the oral cavity.

To insure regular or periodical examinations, the dentist should offer to assume the responsibility of notifying the patient by card as to the time for the next inspection of the teeth. Some will not care for this procedure, while the majority of intelligent patients will appreciate it. The dentist should do no more than offer the suggestion and if there are individual objections, the matter should not be pressed. In every instance the patient should be made to understand that the arrangement is not made for the economic betterment of the dentist, but to facilitate the proper care of the mouth. If this system is adopted, it should be carefully followed up and it should be seen to that there are no chances for error or neglect in sending the notifications regularly and promptly. For this purpose, a monthly card guide system is valuable, the cards for each patient being kept behind the guide for the month in which the notice is to be sent, and moved forward at the proper time.

Examination of Children.—In the case of children, special care should be observed in making the examination. The weight, height, rapidity of bodily growth and general health should be investigated. If these are not normal for the age, effort should be made to find the cause. Inquiry should be made with reference to the health, mode of living and diet of the mother during the period of gestation and nursing. Obtaining of a history with reference to diseases of childhood, methods of feeding of the infant, whether bottle-fed or not, and the food habits of the child is important. Many children are undernourished from an improper dietary, with the inclusion of an excess of sweets, starches and soft foods, with consequent lack of green vegetables, fruits and coarse foods to insure adequate mastication and to stimulate proper bone and tooth formation. Investigation should be made as to whether sufficient fresh air, out-door exercise, sunshine, sleep and rest are insisted on. Poor posture, thumb-sucking and mouth-breathing habits should be investigated. Habits of mastication should be inquired into and a thorough examination be made of both the deciduous and permanent teeth.

Contracted arches, nasal disturbances, such as deflected septum, obstructed nasal spaces, adenoids and diseased tonsils are frequent causes of lowered health and vigor at that period of life, interfering with normal oxygenation and nutrition.

SPECIAL METHODS OF DIAGNOSIS

Thermal Tests of Pulp Disease.—The temperature tests of G. V. Black and Louis Jack for determining the condition of the pulp are still of value, although the introduction of methods of transillumination, the use of the electrical tests and radiography have quite largely improved the facilities of the diagnostician in this regard.

The healthy pulp with its normal protective covering of enamel is subjected to changes of temperature through the application of food substances and drink in the mouth. Under these circumstances it will usually not rebel excessively against temperatures varying between 74°F. to 32°F. for cold and 118°F. to 152°F. for hot applications. However the application of temperature below or above these ranges will produce a quick, sharp contraction pain, passing away immediately on withdrawal of the irritant or stimulant. This reaction is due to transmission of these sensations through the enamel to the dentinal fibrillae, and through them and the odontablastic cells, to the terminal sensory nerve endings in the pulp, and thence to the receptive centers in the brain. Similar response will be elicitated with either heat or cold, and if the tooth be isolated with the rubber dam and the information withheld as to whether heat or cold is being used, the patient will not be enabled to distinguish the difference in the response. In order to determine the individual rate of tolerance, known healthy teeth may be isolated by means of a small square of rubber dam. Then water at a temperature of 80°F. may be applied. Thus by gradually raising and lowering the temperature of the water until slight pain is produced, the normal rate of tolerance for the individual may be determined.

If the enamel be gradually lost, through caries or abrasion or if pathologic disturbances arise in the tissues of the pulp from other causes there will be a gradually increasing response to diminishing degrees of temperature, depending on changes in the circulation in the vessels of the pulp, until the pulp will begin to respond within the ranges of temperature previously mentioned. These circulatory changes are usually progressive in character, beginning with arterial hyperemia and passing through the condition of venous hyperemia to inflammation. If infection occurs, suppuration, and finally putrefactive decomposition supervenes. The circulatory changes are due to irritation, stimulation and finally paralysis of the vaso-motor nerves supplying the vessel walls. The constant irritation of variations of temperature and other irritants, to which the pulp is not normally subject, gradually over stimulate and finally paralyze the sensory nerves of the organ. Heat produces expansion and cold causes contraction of tissue. In closed cases of putresence, heat will also produce expansion of the gases of putrefactive decomposition, with resultant pressure on sensory nerve endings, which, if not yet paralyzed will rebel and manifest painful impressions. In vital or partially vital cases the response elicited will determine the probable condition of the circulatory apparatus and nerve supply. In devital cases, prolonged application of extreme degrees of heat or cold will not produce a response, indicating complete paralysis of sensory and vaso-motor nerves, as well as death and destruction of the other pulp elements. In vital or partially vital cases, the promptness of the response, the character of pain elicited and difference in response to heat and cold applications will offer valuable information to the experienced diagnostician as to the pathologic conditions present.

In the *acute diseases* of the pulp, there is a progressive increase in the response to lesser and lesser variations of temperature with the progress of the disease until moist gangrene begins, when there is a diminishing response until complete death of the pulp occurs. There is also a progressive change in the character of pain elicited. In the early stages (arterial hyperemia) a quick, sharp contraction pain is produced on the application of water below 60°F., the heat of the chip blower or cold air, or the touch of an instrument. The pain should pass away instantly on withdrawal of the irritant. In passive congestion (venous hyperemia) the pain will remain for some time after withdrawal of the test, being a continuous pain accompanied by a feeling of fullness in the tooth. In inflammation (acute pulpitis) the pain will be more easily elicited, with lessened variations of temperature, and will be a dull, throbbing, continuous pain, difficult to relieve. In suppurative conditions (abscess or ulceration of the pulp), there is an increasing response to heat applications, cold often relieving, and the pain produced is of a dull, gnawing character.

In the *chronic inflammations* and *degenerations* of the pulp, including pulp nodules, secondary dentine formation, calcareous, fibroid and other degenerations, the response to the thermal test is usually much slower and less in degree, with a gradual diminution in power, to prolonged applications of iced water, a sharp fragment of ice, ethyl chlorid, or extreme degrees of heat, dependent on the progress of the degenerative process, or on the interposition of layers of calcareous material, which require longer time for penetration of temperature variations. A further discussion of the use of thermal tests is included in the sections on diseases of the pulp.

USE OF THE ELECTRIC CURRENT IN TESTING PULP DISEASES

Various types of electric pulp testing machines have been designed and used in the past for this purpose, such as faradic or galvanic appliances, the violet ray machine and instruments with hand or cheek and tooth electrodes. All of these may now be considered obsolete since the introduction of the modern machines, in which both electrodes are applied directly to the tooth being tested, thus inducing a mild electric current to pass only through the tooth from pole to pole. The current is mildly graduated as indicated on a scale, thus inducing varying degrees of response, dependent on the strength of current and on the pathologic condition present. The modern machines do not require exclusion of moisture from the field of diagnosis and are supplied with coronal electrodes for application to the crown of the tooth and gingival electrodes to be applied between the retracted gum and the gingival margin of gold crowns. In their application, care must be observed that the points do not touch metallic fillings, crowns or the gums.

There is a variation in the response elicited with the pulp tester in different individuals and in different teeth. The anterior teeth respond most readily, the cuspids next and the molars require a higher current. Teeth with receded pulp, secondary dentin formations and degenerated pulps respond less readily, while in devital teeth no response is elicited except in multirooted teeth with vital pulp in one root and devital tissue in others. Teeth affected with pericementoclasia may be tested and recorded at the beginning and during treatment, the difference in current response serving as an index to pulp changes and ultimate recovery. Similar procedures may be resorted to in teeth which have been subject to trauma. A complete electrical chart of pulp response in the teeth of the entire mouth is of value in diagnosis. If doubt exists as to the number of teeth involved in an area of periapical infection or granuloma, the machine will indicate the number of devital teeth affected. It may also be used to test for complete anesthesia in nerve blocking injections. For character of pulp response elicited in various pathologic conditions in the pulp see Chapter XXVI.

TRANSILLUMINATION

Recent improvements in construction of certain types of electric mouth lamps, eliminating the red and orange rays and producing a white equi-chromatic search light have produced better results in diagnosis by this method. Transillumination is valuable for general illuminaton of the mouth and fauces, in detecting concealed proximal cavities, devital teeth, deposits of sub-gingival calculus, pyorrheal and food pockets, congestions of the gum and alveolar processes, diseased roots, disease of the maxillary and frontal sinuses and the mastoid cells. Under its rays, the normal healthy tooth will appear translucent and pink, while the devital tooth will be opaque or dark and discolored. Its use will sometimes reveal congested areas in the periodontium before the rarefied area is visible under the X-ray.

In transillumination of difficult areas, the room must be darkened, or a photographer's focusing cloth should be thrown over the head of patient and diagnostician. The best results are obtained in a dark room specially provided for the purpose. Transillumination is of value under these circumstances in locating congested areas in both soft and bony tissues. These appear pink and translucent in health, while congestion is indicated by discoloration and non-translucency, shadows and opaque areas indicating probable infection and tissue destruction. Diagnosis of the *condition of the maxillary sinuses* may be made by inserting the lamp intra-orally, when, if healthy conditions exist, both eye orbits should appear pink and translucent, the pupils of the eye should appear illuminated and the patient should get a sensation of light when the eyes are closed. There should also be a pink translucency throughout the malar region. This will vary, depending on the varying density of overlying bone and muscle. Another method is the infra-orbital method in which the lamp is placed on the infra-orbital ridge, the light being reflected through the eye-orbit into the antrum, the translucency being noted on the palatal arch. Or the light may be placed in the anterior nares and its effect noted on the palatal arch. In cases of probable infection, the loss of normal translucency will be noted and opaqueness or darkness on both sides will be diagnostic.

For transillumination of the *frontal sinuses*, the lamp is placed under the floor of the sinus well into the orbit and covered with the hand. A normal sinus will appear pink and translucent, probable infections being indicated by opaqueness and darkness of the area. Transillumination of the *mastoid cells* is accomplished by placing the lamp into the external auditory canal and noting its effect on the mastoid region behind the ear. Transillumination should not be relied upon alone in diagnosing these disturbances, but, when correlated with roentgenology and other procedures it may be considered a valuable aid in determining the conditions present.

ROENTGENOLOGY IN ORAL DIAGNOSIS

The introduction of the Roentgen ray into dentistry has caused increased interest in oral diagnosis and is undoubtedly one of the most important factors contributing toward correct determinations of the character and extent of many oral pathologic disturbances. Its usefulness has increased to such a degree that it is now considered a necessity in the modern dental office. It is the practice of some dentists to refer patients to specialists in this field for roentgenographic diagnosis. This is a great disadvantage, for several reasons. Frequently the specialist is not informed as to the systemic, mechanical and other aspects of the individual case referred to him for diagnosis, and, consequently, does not always produce the best results under these circumstances.

Also, the loss of the time required to obtain the desired information, in addition to the inconvenience to the patient is an important factor. During root therapy and other procedures, it is frequently desirable or necessary to record progress, or to check up on instrumentation procedure during the handling of the case. In many of these conditions and others unnecessary to mention, at least a dental unit is highly desirable as a part of the office equipment, so that it may be resorted to at any time. Where the making of specially difficult extra-oral exposures is necessary, these cases may be referred to the roentgenologist, if the capacity of the machine in use is inadequate, or the experience of the operator is limited in making this type of roentgenogram.

It is not the intention of the author to discuss in this volume the theory of the X-ray or the various technical procedures incident to its production and use. The existence of adequate text-books and the organization of special courses on Roentgenology in the dental schools precludes the necessity for the discussion of this phase of the subject in a text-book on Operative Dentistry. However, its use as a diagnostic procedure and the interpretation of radiograms is dwelt on here and throughout the book.

Interpreting Radiograms.—Special training in the interpretation of radiograms, which can come only from close observation, long experience and knowledge of the anatomy, histology and pathology of the parts shown in the picture, is essential. It is a mistake to attempt to make a final interpretation of the picture without a knowledge of the history and clinical aspects of the case. This is one of the shortcomings of depending on the diagnosis of the specialist in radiology, who, in many instances, never sees the patient, and is an additional reason why the dentist should make his own radiograms and learn the art of interpreting them with the patient available for that purpose.

The radiogram does not depict disease. It is merely a record upon the film or plate of the radiability of the various tissues through which the rays have passed. The soft tissues of the cheek, gums and mucus membranes are *radiolucent*, the ray passing through them readily, while bone and tooth, owing to their density, interfere with the passage of the ray and are *radiopaque*. Enamel is the most opaque tissue in the body, owing to its density, while dentin and cementum vary in radiability for the same reason. Gold and silver are also quite radiopaque. Changes in the normal radiability of tissues are produced by pathologic processes, surgical and medicinal treatment, these changes being apparent on the radiogram. Figs. 58 and 59. The changes in radiability are merely pictures or shadows of structural abnormalities or pathologic changes in the tissues radiographed. Microscopic changes in structure, such as those incident to pulp pathology, cannot be distinguished by radiology. However, the grosser changes in the pulp may frequently be observed, such as secondary dentin formation and pulp nodules.

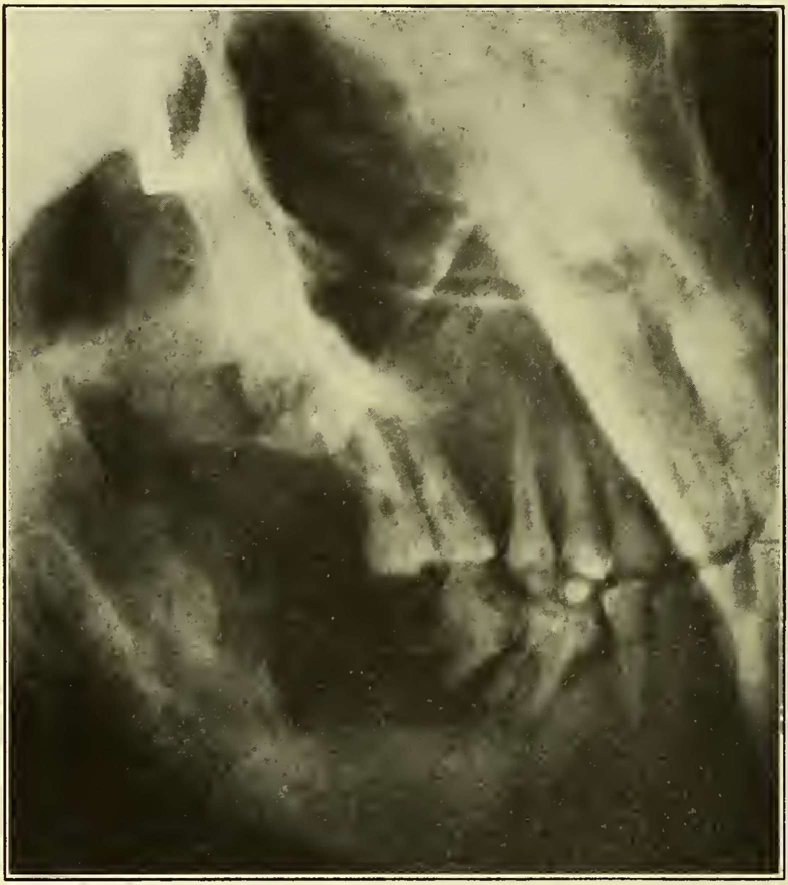


Fig. 58.—Osteomyelitis of mandible in molar region.

Areas of decay on the crowns of teeth may readily be detected and loss of bone at the alveolar crest or at the apex of the tooth is easily observed in good radiograms. Figs. 60 to 64. Decalcification of tooth or bone from pathologic processes shows as a shadow on the film. It is an error, however, and unscientific, to interpret these shadows as infection. Infection is determined by the microscope, and not by the X-ray.

Errors in diagnosis frequently arise from interpreting shadows of anatomical landmarks as areas of bone destruction or "infection." This is particularly true in case of the mental foramen, the incisive foramen, the maxillary sinuses, the nostrils and the coronoid process. Figs. 65 to 70. Errors in this regard often arise with inexperienced diagnosticians, sometimes due to improper angulation in taking the picture, resulting in distortion, fore-shortening or elongation of shadows. Figs. 71 to 75. Particular care should be observed to avoid these errors in connection with the incisive foramen, which owing to distortion may simulate in appearance an abscess at the apex of an upper central incisor, or in connection with the mental foramen in close juxtaposition to the

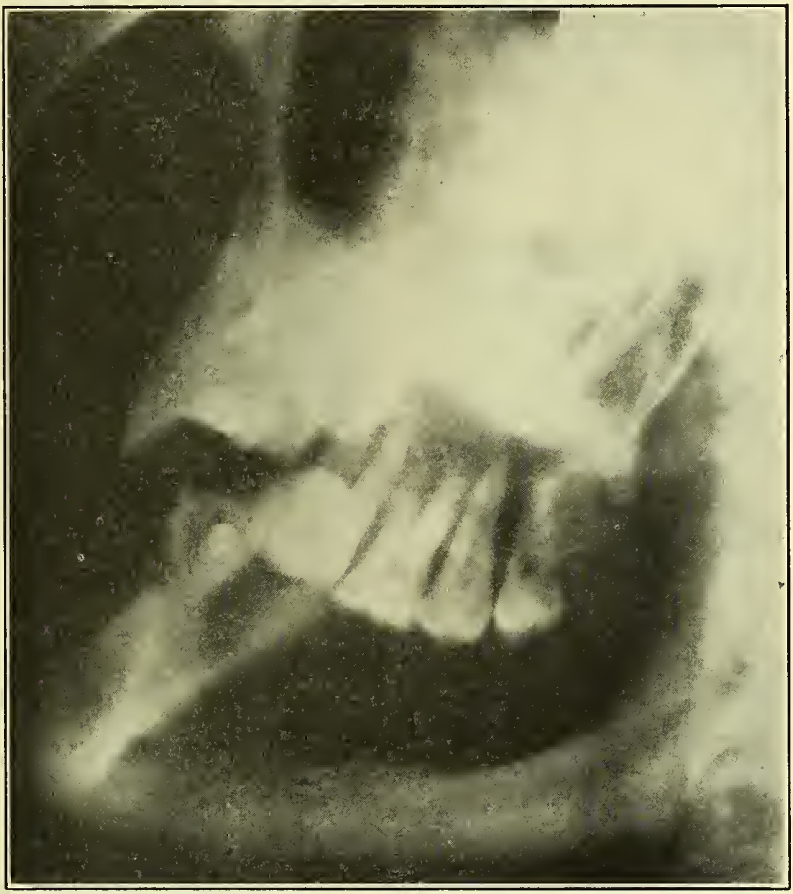


FIG. 59.—Osteomyelitis after treatment. Mandibular process destroyed, leaving body of mandible intact.

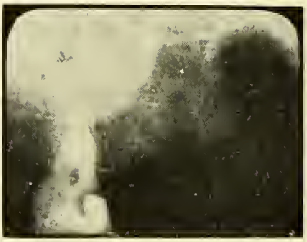


FIG. 60.—Caries under filling.

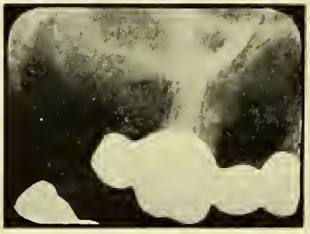


FIG. 61.—Caries under crown, second bicuspid.

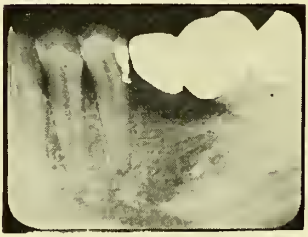


FIG. 62.—Caries under filling. Darker area in first molar region indicates bone undergoing repair.

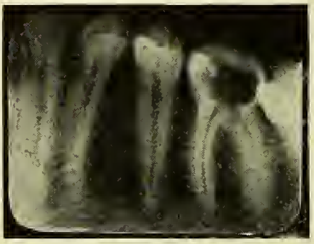


FIG. 63.—Marked caries involving pulp.

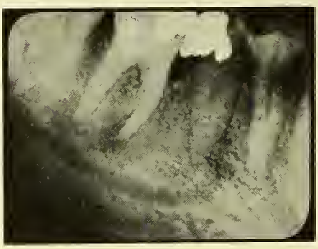


FIG. 64.—Chronic alveolar abscess, mesial root of molar; alveolar crest absorption from poor filling in bicuspid; mental foramen between apices of bicuspids.

FIG. 65.—Edentulous maxilla, incisor and cuspid region, showing anterior palatine foramen: and above it the nasal cavity.

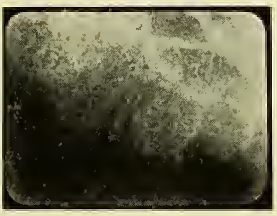


FIG. 66.—Normal edentulous bicuspid and molar region, showing antrum and malar shadow.

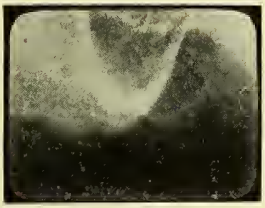


FIG. 67.—Edentulous maxilla, malar region, showing antrum and shadow of malar process.

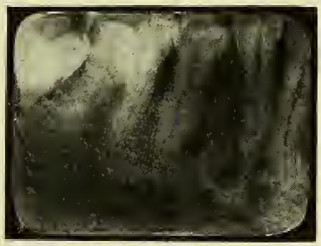


FIG. 68.—Mental foramen mesial to second bicuspid. Inferior dental canal.

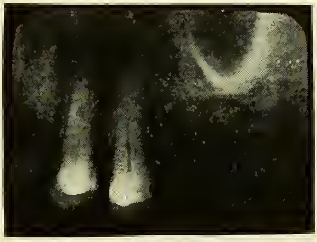


FIG. 69.—Retained roots. White U shaped object is shadow of malar bone.

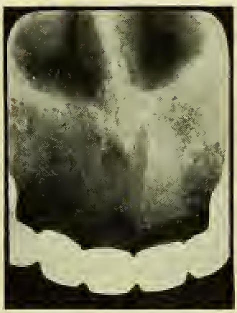


FIG. 70.—Nasal cavities.

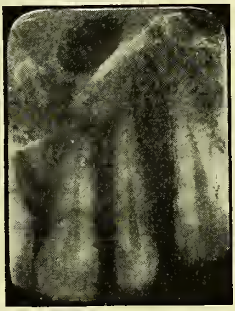


FIG. 71.—Correct angulation.

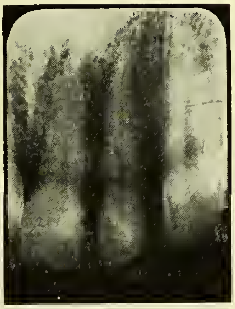


FIG. 72.—Elongation due to insufficient angulation. Same teeth.

apex of a lower bicuspid root. Similarly, a part of the ramus of the mandible may occasionally be mistaken for an upper third molar root.

The various filling materials, owing to differences in density have varying degrees of radiability. Gold and amalgam fillings, gold inlays, gold crowns and posts are radiopaque and show white on the film. Guttapercha and oxyphosphate of zinc cements are also radiopaque and have a similar appearance. Silicate cements and porcelain are more or less radiolucent and show dark or black shadows on the film. Figs. 74 and 76.

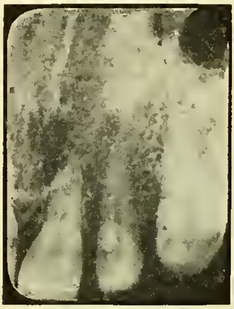


FIG. 73.—Foreshortening due to excessive angulation. Same teeth as Fig. 72.

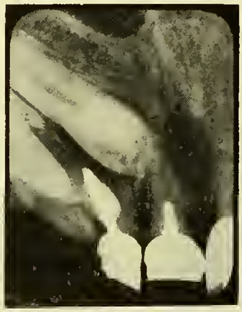


FIG. 74.—Distorted view showing apparent perforation of lateral root by crown post.

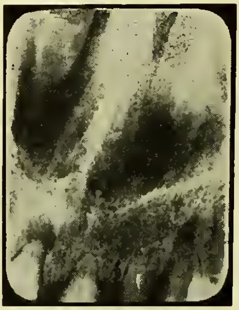


FIG. 75.—Marked foreshortening due to faulty angulation and poorly placed film.

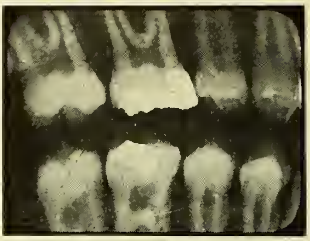


FIG. 76.—Amalgam fillings.

Value and Uses of Roentgenology.—Radiographic examination is indicated in all cases, unless it is evident that the teeth are vital and healthy. New patients or patients who have not had roentgenographic inspection for some time should be subjected to routine examination of all the teeth. Fig. 77. The periodic examination of patients in this manner is a valuable procedure in diagnosis. For detecting surface defects, sub-gingival calculus and periodontic disturbances of alveolar bone the use of bite-wing films is valuable. In this method, the complete denture may be radiographed with five bite-wing films, thus reducing the time and expense of the operation. This method is only avail-

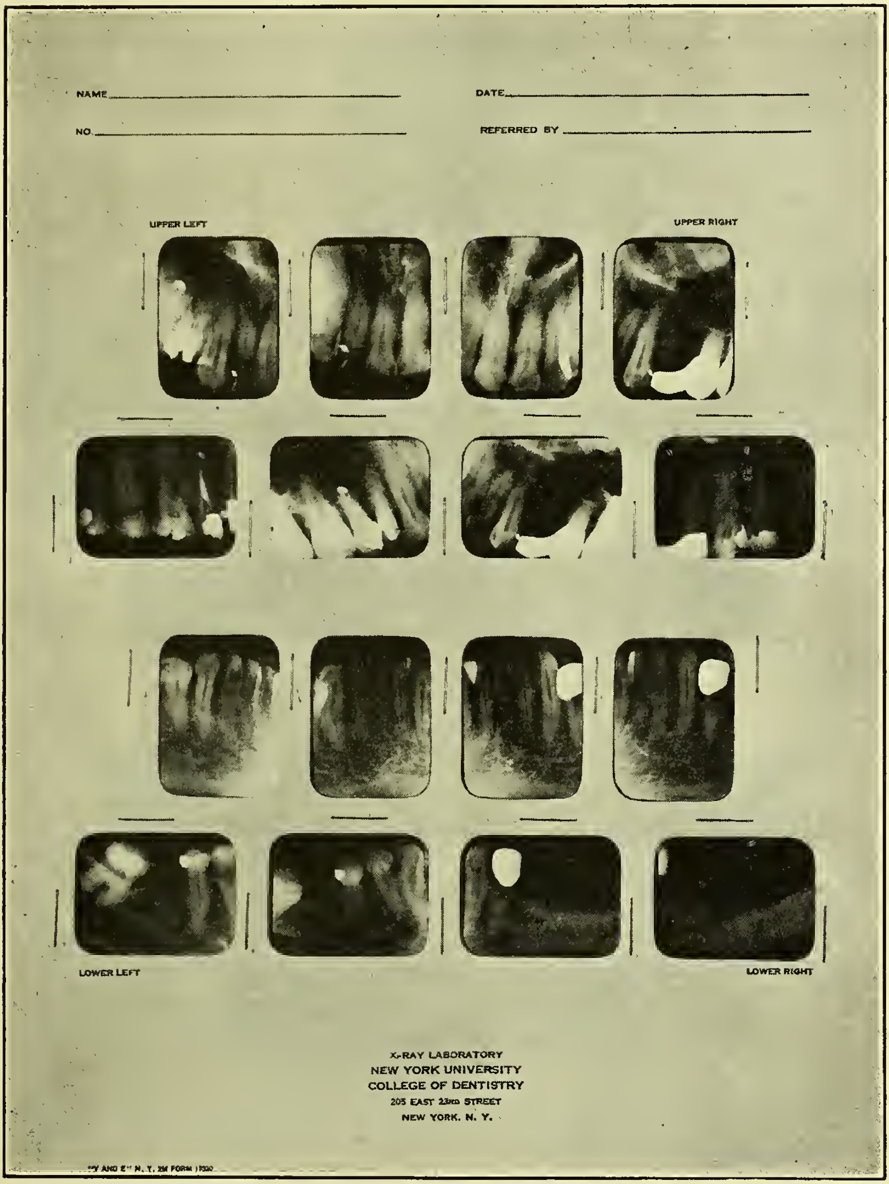


FIG. 77.—Sixteen film series mount. Two views at different angles are obtained of each tooth.

able, however, in cases where the condition of the periapical tissues is known through previous recent exposures, since the bite-wing films used for this purpose show only the crowns and gingival third of the roots.

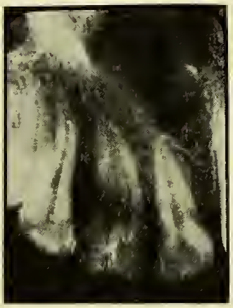


FIG. 78.—Twin laterals.

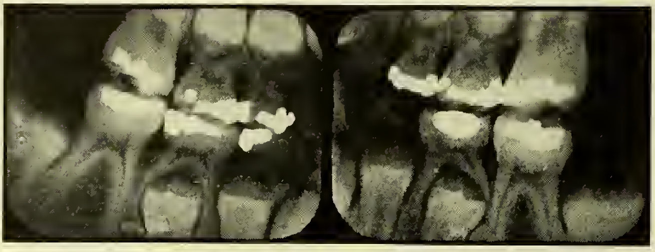


FIG. 79.—Right and left sides. First permanent molars in place and carrying large fillings. Erupting bicuspids and second molars.

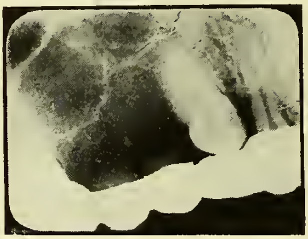


FIG. 80.—Impacted tooth erupting under bridge.

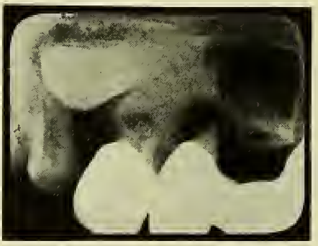


FIG. 81.—Impacted cuspid. Ill fitting crowns on bicuspids, marked apical absorption on second bicuspid.

The use of roentgenology in dentistry is valuable for determining the fifteen following conditions:

1. The progress of dentition. The state of development or absorption of the teeth at various stages is readily determined. Misplacement of tooth germs, absence of deciduous or permanent teeth from the jaw, and prolonged retention of deciduous teeth are important conditions

which concern the general practitioner, the orthodontist and other specialists. Figs. 78 and 79. These are all revealed by the X-ray;

2. Integrity of teeth and their supporting structures when they are to be used as abutments in bridge work or as anchorages for removable appliances. All teeth to be used for this purpose should be subjected to radiography before the construction of the appliance is begun;

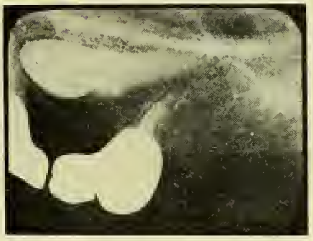


FIG. 82.—Upper cuspid impaction.

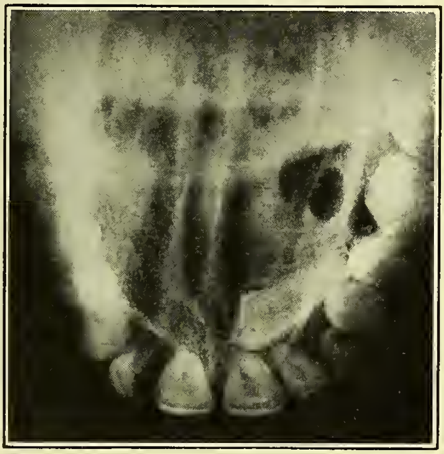


FIG. 83.—Impacted permanent cuspid. Temporary cuspid still in position.

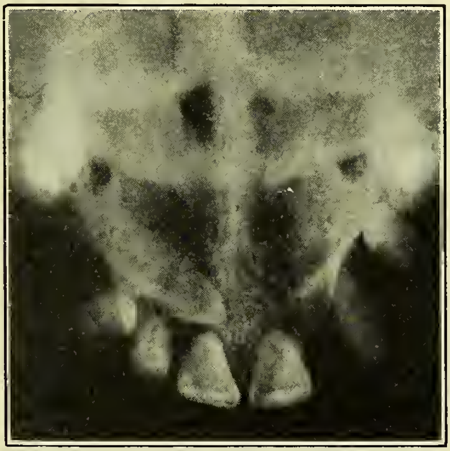


FIG. 84.—Impacted cuspid. Bicuspid erupted forward next to lateral.

3. For the detection of unerupted or impacted teeth or concealed roots and for determination of the condition of the bone surrounding them. Figs. 79 to 103;

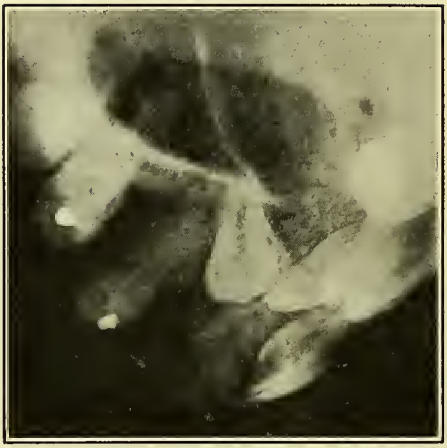


FIG. 85.—Impacted cuspids.

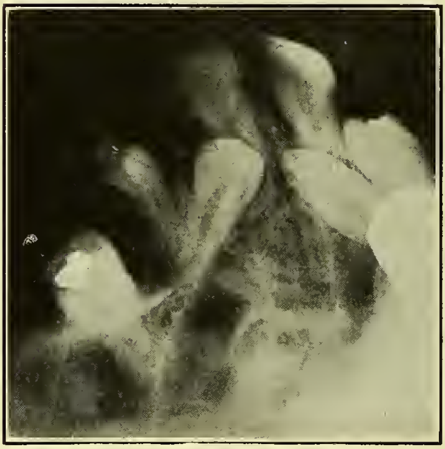


FIG. 86.—Impacted cuspids.

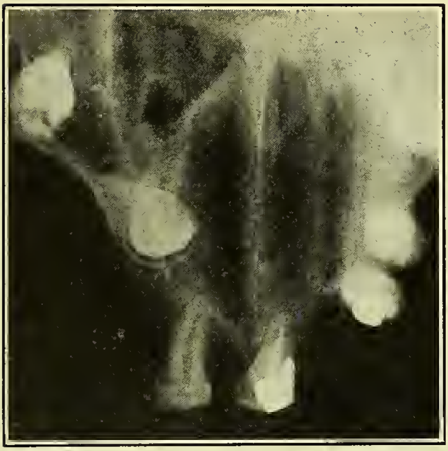


FIG. 87.—Left impacted cuspid.

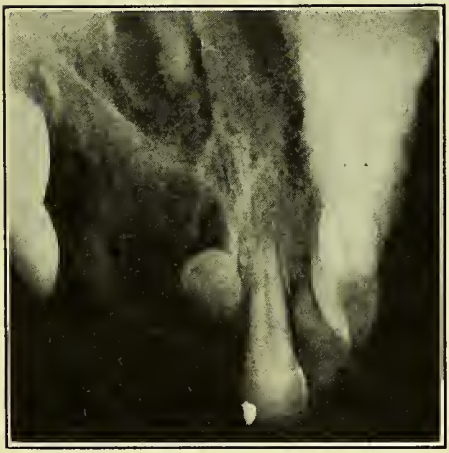


FIG. 88.—Upper incisor impaction.

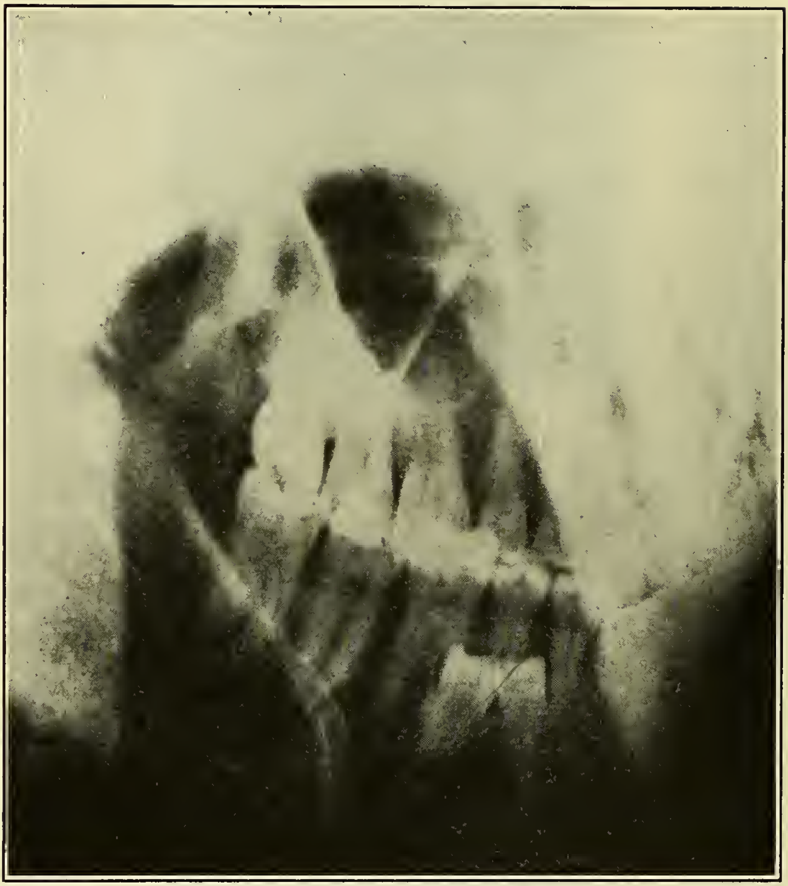


FIG. 89.—Two impacted supernumerary bicuspids. The hyoid bone shadow is seen as an oblique line extending from the distal of the third molar to center of mandible. This was due to swallowing by the patient when the exposure was made.

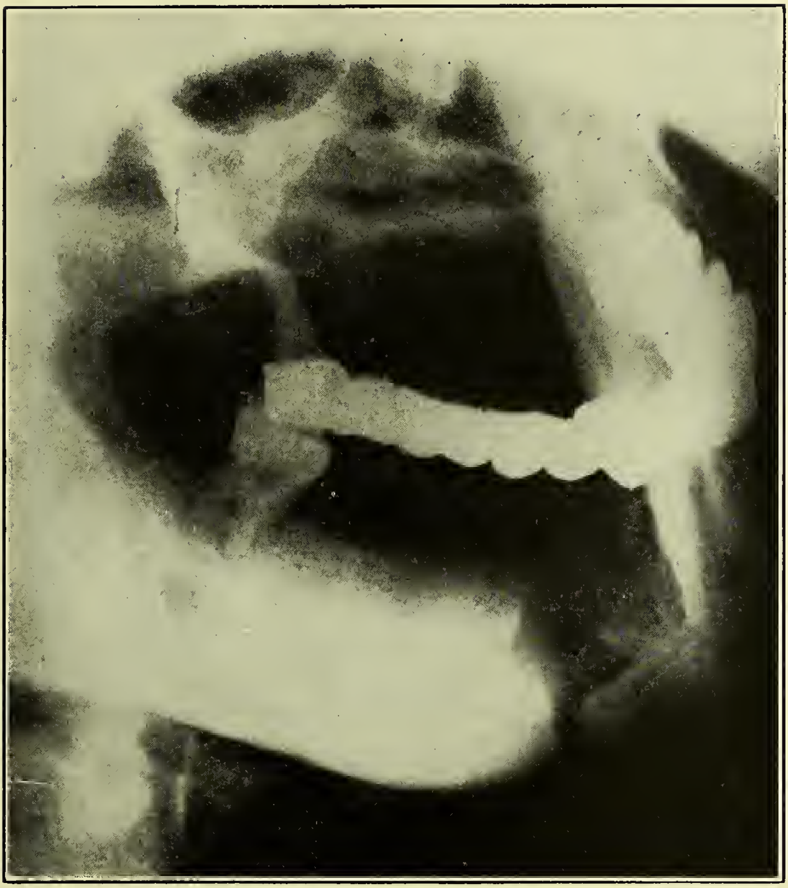


FIG. 90.—Inverted impacted mandibular cuspid surrounded by cyst. Full upper fixed bridge.

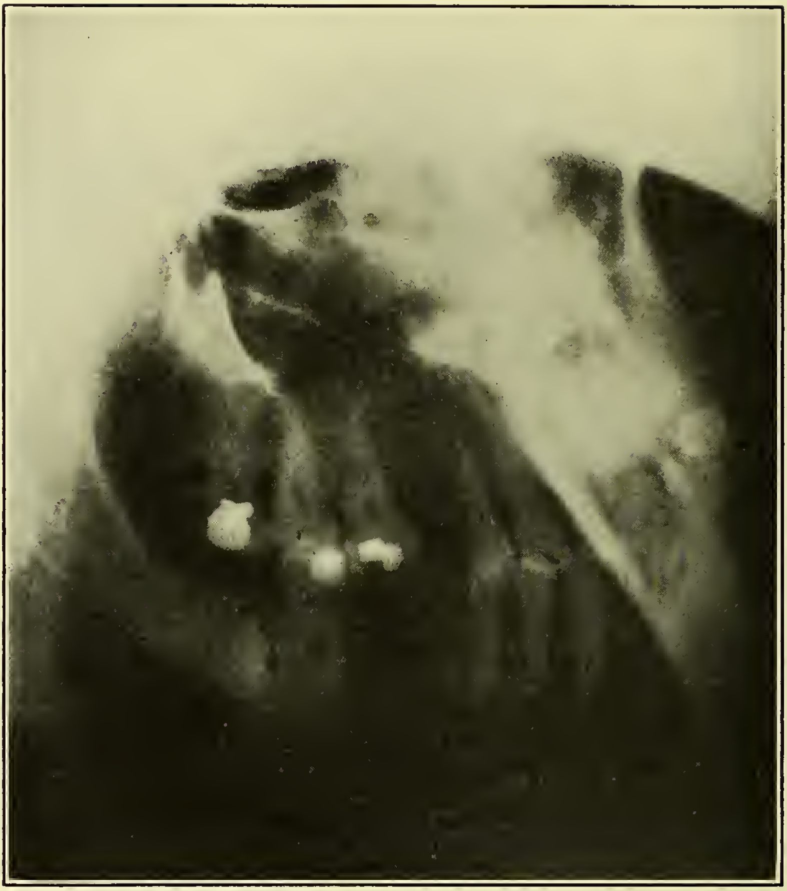


FIG. 91.—Horizontal impaction, lower third molar.

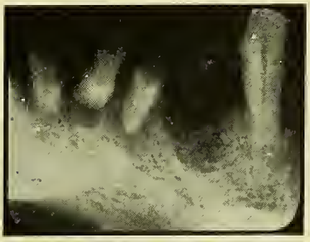


FIG. 92.—Retained roots.

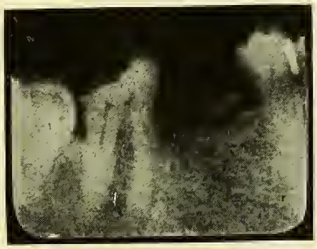


FIG. 93.—Root in soft tissues.

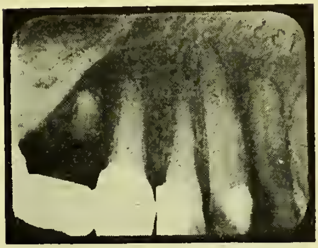


FIG. 94.—Retained root under bridge.

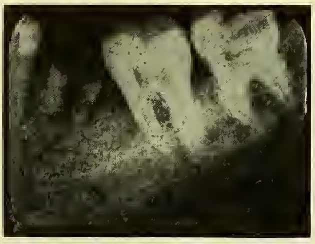


FIG. 95.—Molar roots.

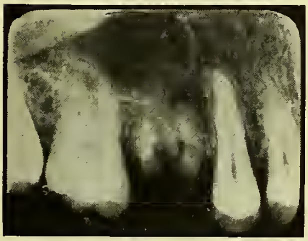


FIG. 96.—Molar roots.

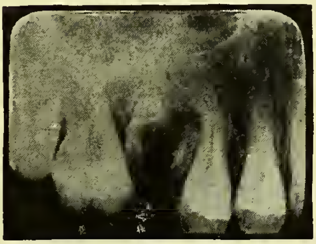


FIG. 97.—Molar roots.

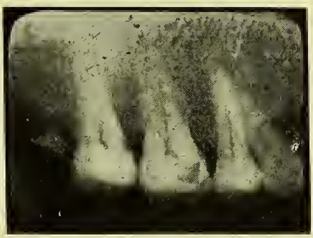


FIG. 98.—Third molar root in soft tissues.

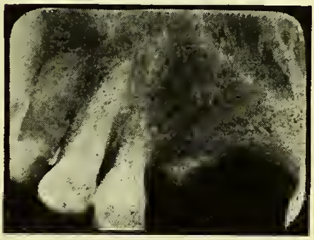


FIG. 99.—Retained root apex.

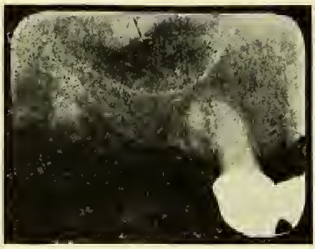


FIG. 100.—Retained bicuspid and molar roots.

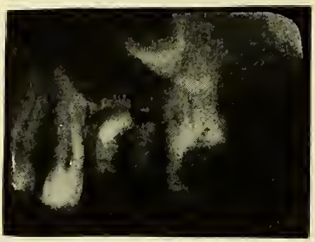


FIG. 101.—Retained roots, caries second molar.

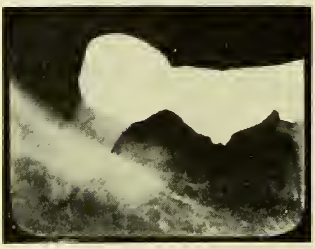


FIG. 102.—Retained roots under bridge. Dark area at apex of molar is superimposed inferior dental canal.

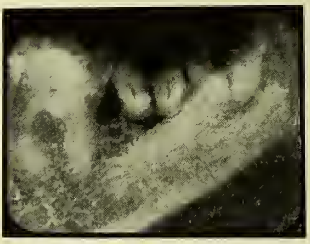


FIG. 103.—Retained lower molar roots.

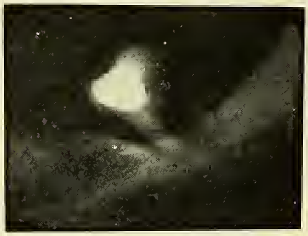


FIG. 104.—Fractured distal root, with marked periodontoclasia.

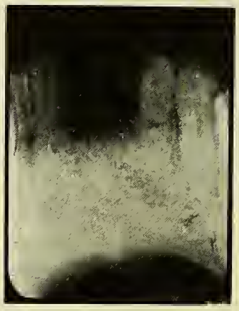


FIG. 105.—Fractured cuspid.

4. To determine the extent of traumatic injury of the teeth from falls, blows and similar accidents, and to diagnose probable fracture of a root containing the dowel of an artificial crown. Figs. 104 and 105;

5. For diagnosis of cavities of decay on proximal surfaces, for determination of the depth of the decay and the presence of decay under fillings. Caries appears on the film as a dark area, due to loss of tooth substance and to decalcification of dentin and enamel, increasing the radiability of the affected area;

6. For detecting overhanging or imperfectly finished margins of faulty proximal fillings or crowns. For the discovery of faulty contacts or undue proximal separations with resultant food pockets;

7. For diagnosing secondary dentin formation, receded pulp chamber walls, pulp nodules and calcific degenerations of the pulp. Adventitious dentin or pulp nodules, if they have progressed to important size, may readily be seen, while calcific degeneration and small nodules will decrease the radiability of the pulp. Fig. 106;

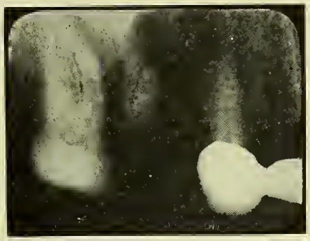


FIG. 106.—Retained roots. Large pulp nodule in molar.

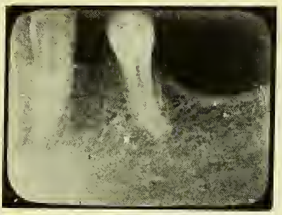


FIG. 107.—Socket filling in with new bone six months after extraction.

8. For determining the length, state of development, number and tortuosity of roots, preceding attempts at root therapy; also for determining progress at different stages in opening root canals, and for checking up root canal fillings on the completion of the operation; also for detecting the presence during examination of the mouth of defective root canal fillings. Guttapercha and other modern root canal filling materials are radiopaque under the roentgen ray;

9. For diagnosis of hypercementosis or resorption of roots;

10. For diagnosis of periapical disturbance. On a normal tooth, the peridental membrane may be seen as a continuous radiolucent line encircling the root. Surrounding this will be noted the lamina dura, exhibited in the form of a radiopaque line. The trabecula of bone at

the apex and outside of this line should appear homogeneous with the surrounding bone.

In some instances the apical space surrounding teeth recently infected or infected with micro-organisms of low virulence may appear perfectly healthy in the X-ray film, while teeth suffering from the effects of traumatic occlusion, or chronic low grade inflammatory disturbances of the apical tissues may exhibit an apparent rarefying or sometimes a condensing process in the surrounding bone. Consequently, it should be remembered that a change in the appearance in the area at the apex does not always point to the possibility of infection. Many errors in diagnosis are thus made from an imperfect understanding of this fact.

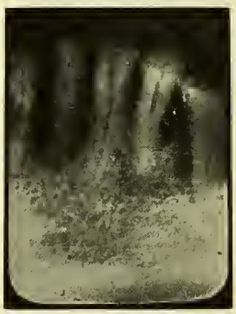


Fig. 108.—Marked alveolar absorption.

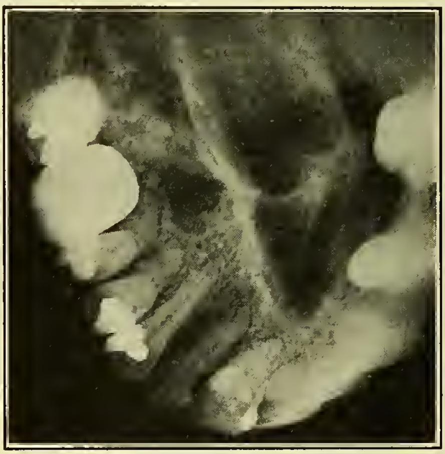


Fig. 109.—Bird's eye view of left maxilla.

The radiogram is, then, not an infallible guide in the diagnosis of infective conditions of the periapical tissues. Infections can be positively diagnosed by the microscope. In case of bone destruction at the apex from granuloma, a radiolucent area of varying size will show in the film, depending on the size of the cavity formed. In chronic cases, occasionally, resorption of the root apex or a denuded, calculus-incrusted root end is revealed in the picture;

11. For noting the progress of reconstructive changes of alveolar bone, following the treatment and healing of periapical infections. Fig. 107. It usually requires from six to twelve months intervals before the filling-in of new and healthy bone structure may be observed in cases of this nature, and often two years may elapse before the reappearance of normal-looking bone:

12. For diagnosis of the progress of alveolar crest destruction and pocket formation in peridontoclasia, and also the rate of the healing process during and following treatment. Fig. 108. Insertion of a guttapercha point to the bottom of the pocket before the exposure is made is of assistance in determining the depth of pockets;

13. For diagnosis of follicular, dentigerous and radicular cysts. Figs. 109, 110 and 111;

14. For diagnosing pathologic conditions of the maxillary, ethmoidal and frontal sinuses, for which extra-oral or head exposures are necessary. Figs. 112 and 113. Inflammation and pus formation in these cavities are revealed by the presence of radiopaque areas on the film;

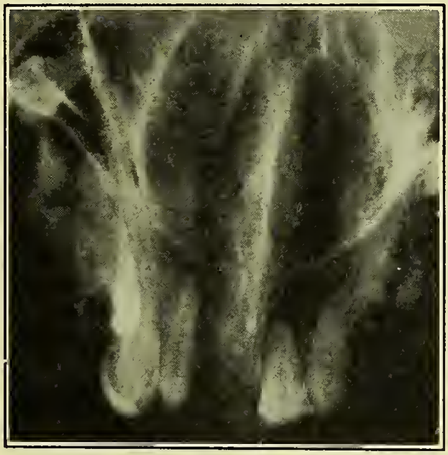


FIG. 110.—Cysts.

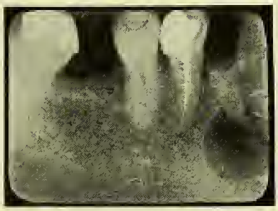


FIG. 111.—Retained root with cyst at apex.

15. For diagnosing fractures of the maxilla and mandible. Figs. 114, 115 and 116.

Stereoscopic Radiography.—With an ordinary radiograph, flat surfaces are shown, only the length and width of objects radiographed being represented. With stereoscopic radiograms, viewed with the stereoscope, the third dimension, viz. depth is revealed. This is a very valuable consideration to the diagnostician, enabling him to determine more clearly the relationship of objects to each other. Many of the doubtful features of the ordinary flat shadow picture are thus eliminated by this process, resulting in a more perfect diagnosis. The stereoscope reveals a translucent model of the teeth with various roots standing out distinctly. Root canals are clearly shown and any imperfection in root-canal fillings readily seen. The accidental perforation of a root filling or crown post may frequently be readily determined, and the relative position of unerupted, impacted or supernumerary teeth is easily seen. It also offers an excellent means of determining the relationship of teeth, abscesses or cysts to the labial, buccal or lingual plates of overlying bone.

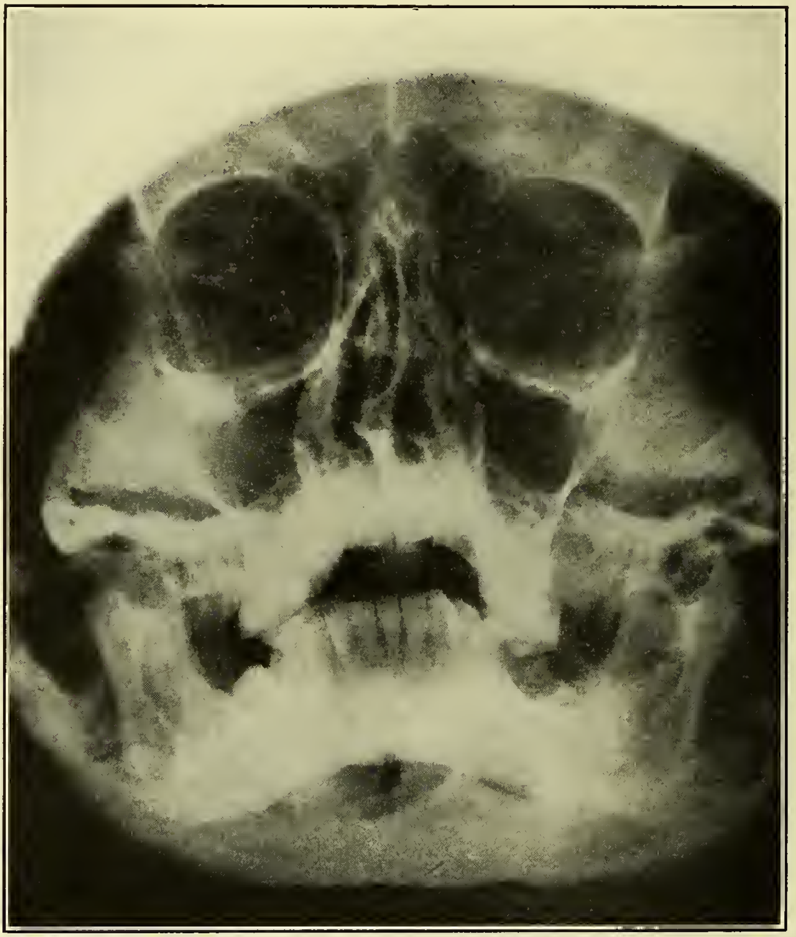


FIG. 112.—Frontal, ethmoidal and maxillary sinuses normal. Postero-anterior view.

In this process, two exposures are made of the regions involved, from points about two and one-half inches apart, which is the average pupillary distance. The patient must not move during the change of the films and they both must be taken on the same plane. The modern X-ray machines are now provided with a special stereoscopic shift;

and a special stereoscope for viewing the radiograms, together with suitable film mounts are obtainable. Familiarity with the following official nomenclature is important to the student in discussion of radiographic subjects.

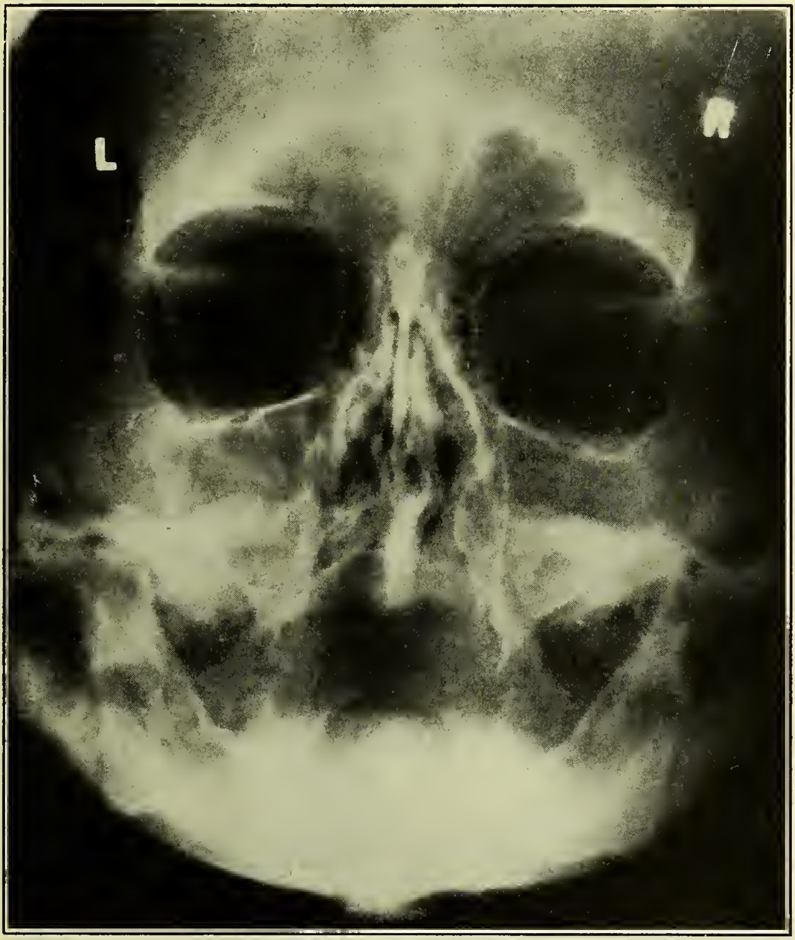


FIG. 113.—Maxillary sinusitis, both sides.

Nomenclature.—Roentgen ray. A ray discovered and described by William Konrad Roentgen in 1895.

X-ray. Same as roentgen ray.

Roentgenology. A study and practice of the Roentgen ray as applied to medical and dental science.

Roentgenologist. One who practices roentgenology.

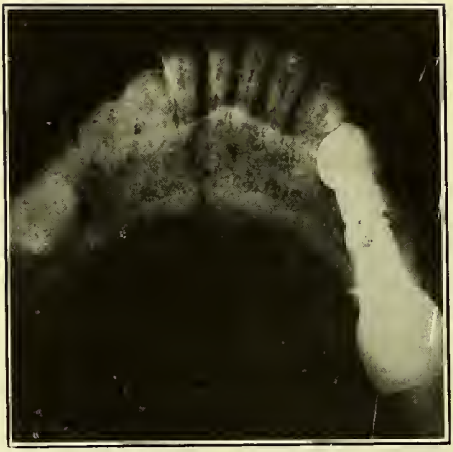


FIG. 114.—Fracture of mandible in anterior region.

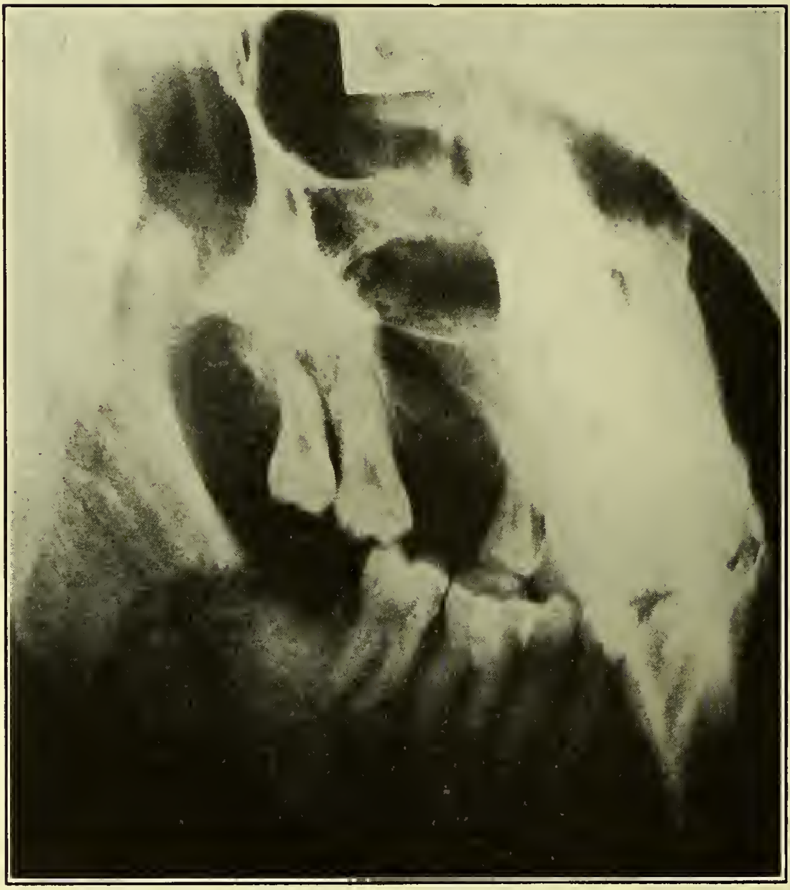


FIG. 115.—Complete fracture at angle of mandible.

Roentgenogram. The shadow picture produced by the roentgen ray.

Roentgenoscope. An apparatus for examination with the fluorescent screen excited by the roentgen ray.

Roentgenograph. (verb) To make a roentgenogram.

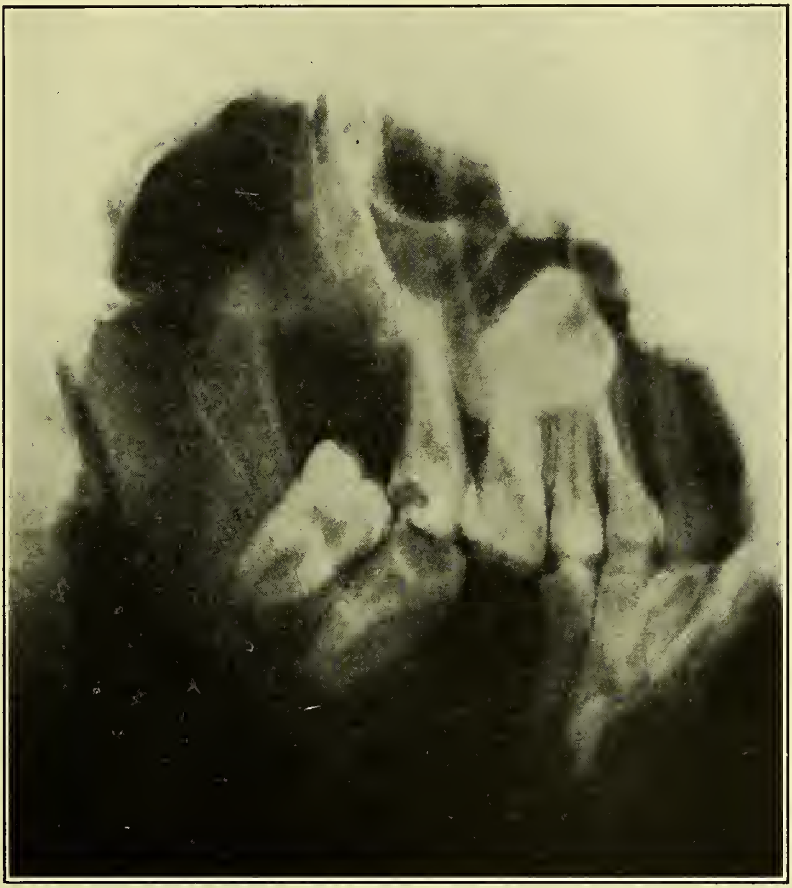


FIG. 116.—The object in the region between the upper second bicuspids and first molar having the appearance of a foreign body is a molar in the mandible of the opposite side; thrown there by angulation.

Roentgenography. The art of making roentgenograms.

Roentgenize. To apply the roentgen ray.

Radiogram. Same as roentgenogram.

Radiograph. Same as roentgenograph.

Skiagraph. Same as radiogram, though almost obsolete.

Radioparent. Offering no resistance to the passage of the ray.

Radiolucent.	Offering slight resistance to the passage of the ray.
Radiopaque.	Impervious to the ray.
Radiodontist.	One who specializes in dental X-ray work.
Radiodontic.	The application of the X-ray to dentistry.

Bibliography

1. Ferris, H. C.: Jour. Amer. Dent. Assoc., Sept. 1927, p. 1693.
2. Burchard, H. H. and Inglis, O. E.: "Dental Pathology and Therapeutics," 5th ed., Lea and Febiger, Philadelphia, p. 416.

Greenfield, A. L.: "Interpretation of Dental Radiographs," Ritter Dental Mfg. Co., Rochester, N. Y., 1928.

McGehee, W. H. O.: Diagnosis of disturbances of the oral cavity, Dental Cosmos, Nov. 1926, p. 1033.

McGehee, W. H. O.: Basal principles involved in the science and art of diagnosis, Jour. Tenn. State Dental Asso., July and Oct., 1933.

Hirschfield, Isador: Interdental canals, Jour. Amer. Dent. Assoc., April 1927.

Hirschfield, Isador: Some types of periodontoclasia and diagnosis of symptoms, Dental Items of Interest, Nov. 1926.

Hirschfield, Isador: Study of skulls in Amer. Museum of Nat. History in relation to periodontal diseases, Jour. Dent. Research, vol. V, no. 4, p. 241.

Wald, Sam'l Stanley: Improved methods of dental stereographic radiography, Dental Cosmos, LXXI, May 1929.

Patrick, Hugh T.: Trifacial neuralgia, Jour. Amer. Dent. Assoc., Dec. 1928, p 2207.

Hume, E. C.: Value of roentgenogram in oral diagnosis, Jour. Amer. Dent. Assoc., Oct. 1929, p. 1846.

Simpson, C. O.: Radiographic diagnosis, etc., Jour. Amer. Dent. Assoc., July 1927, p. 1175.

Thoma, K. H.: Comparison of clinical roentgen and microscopic findings on infected vital pulps, Jour. Dental Research, Aug. 1929, p. 447.

Leigh, R. W.: Studies of the enamel, Jour. Amer. Dent. Assoc., Apr. 1927, p. 592.

Ney, W. Winfield: Trigeminal neuralgia, etc., Jour. Dental Research, Feb. 1928, p. 31.

Schultz, L. W.: Trifacial neuralgia, Jour. Amer. Dent. Assoc., Feb. 1930, p. 297.

Kennedy, Foster: Trigeminal neuralgia, Jour. Dental Research, April 1928, p. 183.

Orban, Balint and Mueller, Emil: The gingival crevice, Jour. Amer. Dent. Assoc., July 1929, p. 1206.

Box, Harold K.: Evolution periodontal pus pocket, Canadian Dental Research Foundation Bulletin, May 1921.

Hodgson, E. C.: Intra-oral stereo-radiography, Jour. Amer. Dent. Assoc., Dec. 1927, p. 2173.

Raper, Howard R.: Value of the radiogram in general practice, Jour. Amer. Dent. Assoc., Dec. 1927, p. 2250.

Stallard, Harvey: Residual food odors of the mouth, Jour. Amer. Dent. Assoc., Sept. 1927, p. 1689.

CHAPTER III

PREVENTION OF ORAL DISEASES

ORAL HYGIENE—PREVENTIVE DENTISTRY—ORAL PROPHYLAXIS

Oral Hygiene may be defined as that branch of sanitary science which treats of the health of the mouth and its preservation. By oral prophylaxis is meant that branch of dental science which has for its object the preservation of the health and cleanliness of the oral cavity: *Preventive Dentistry.* The terms are synonymous and include all those measures designed to maintain the tissues of the mouth in a normal condition and to prevent pathological disturbances of these parts. At present, however, the term "oral prophylaxis" is largely used to designate those measures concerned in the removal of deposits from and cleansing of the teeth.

GENERAL CONSIDERATIONS

The majority of the operations which the dentist is called upon to perform at the present time are of a curative or restorative nature. This is due largely to the fact that the public has not yet been educated as to the desirability of, and necessity for, strict cleanliness of the mouth and teeth at all times. Also it may be attributed to our present lack of knowledge of diagnosis and the causes and pathology of the diseases to which the oral tissues are subject, as a result of which our methods for the prevention and early treatment of these diseases are ineffective.

Since the advent of preventive medicine, the realization of the necessity for educational propaganda along dental lines has received a marked impetus, and much good has been accomplished through the concerted efforts of the profession in the inauguration of oral hygiene campaigns. The well-worn saying: "A clean tooth never decays," is only relatively true, but if patients could be made to realize the importance of maintaining at all times absolute cleanliness of the soft tissues of the mouth, as well as of every surface of all the teeth of a denture, dental caries, as well as periodontal disturbances, would be largely prevented.

If the time ever arrives when these conditions can be accomplished, it readily may be seen that the chief functions of the dentist of the future will be preventive, or prophylactic, rather than restorative and curative in character. Many restorative operations of necessity, still will have to be performed, even under these circumstances, and there still will be plenty of work of that nature to be done, but it will be much less in extent than at the present time, and secondary in importance to prophylactic operations.

The future in this regard lies largely in the hands of the dental profession, and it is incumbent on each member of that profession to realize that one of his chief duties is the education of his patients as to the importance of oral hygiene and its bearing on the health, mentality and morality of the community in which his activities lie. One of the chief duties of the dentist should be the discussion of matters of this nature with patients at the chair, as well as at public gatherings and in the press, when opportunities permit. Definite and detailed instructions should be given the patient, as to the proper methods of daily and regular cleansing of the oral cavity, mentioning by name the brush, the dentifrice and other adjuncts preferred, as well as describing the methods of their application. Mothers should be given definite instructions, as to the care of the teeth of their offspring, and the necessity

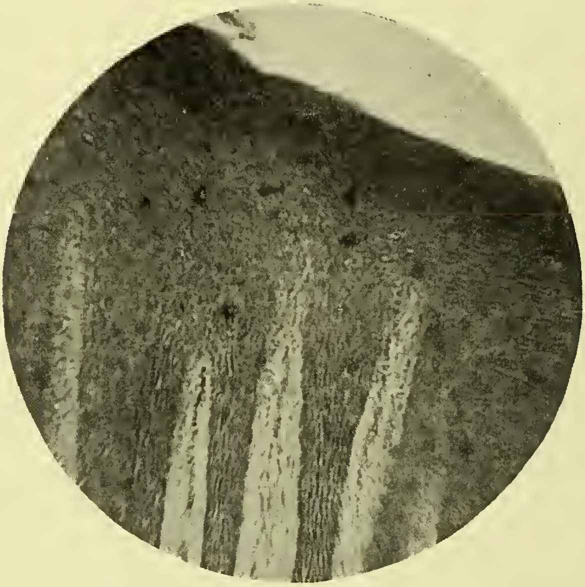


FIG. 117.—External surface of the marginal gingiva, showing capillary loops. (Courtesy of Dr. Harold K. Box.)

of these procedures should be fully explained, bringing out their bearing on the health of future generations.

In reviewing the literature one is overwhelmed with the immense amount of material recently contributed in text-books and the journals on this subject. So conflicting are the statements and views of the various writers on the different phases of the matter that it must be admitted that our present knowledge is somewhat unreliable and unstable, and that some of the various measures advocated for relief are more or less empyric and unscientific.

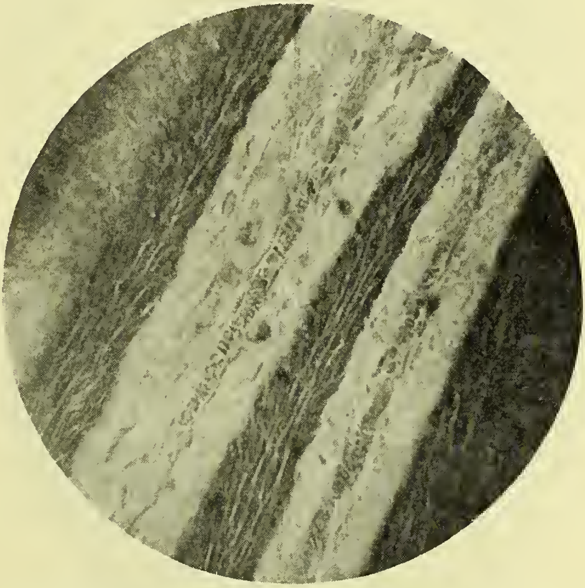


FIG. 118.—Connective tissue papillae (white areas) extending into epithelium of marginal and cemental gingiva. An arteriole is seen in smaller papilla and an arteriole and venule (less distinct) in larger papilla. (Courtesy of Dr. Harold K. Box.)

Before the profession can make very many further advances in preventive measures, it will be necessary for the histologists to reach more definite and sane conclusions in regard to the embryology and microscopic structure of the tissues involved. In studying the reported findings of these investigations during the past few years, there are found many conflicting statements with reference to the processes incident to the origin and development, the histologic structure, innervation, source and character of nutrition and vital relationships of the teeth and supporting structures. This leads to confusion as to the value of endocrinology, calcium metabolism and other measures in their bearing on tooth and bone development and maintenance. It is highly important that these conflicting views, due probably to different methods of staining, microscopic technic and interpretation, be cleared up. Conflicting views of various authorities as to the causes, pathology and preventive procedures necessary, indicate that at present no definite methods of control have been discovered by which immunity to oral affections may be established; and it must be conceded that, regardless of the immense amount of effort and research expended, we are as yet just on the border line in the field of prevention and that vast additional researches are necessary before much further progress can be made. The mass of material presented and the present concentration of the best minds in the profession on the problems incident to prevention of dental disease is a healthy sign and surely indicates that the profession is desirous and capable of solving her problems in this direction, just as she has been in the past on many previous occasions. Certainly the research and scientific investigations in progress by the profession of dentistry compare favorably in character and amount with similar work of the medical profession in their endeavors to solve their individual problems of prevention. The study of methods whereby disease

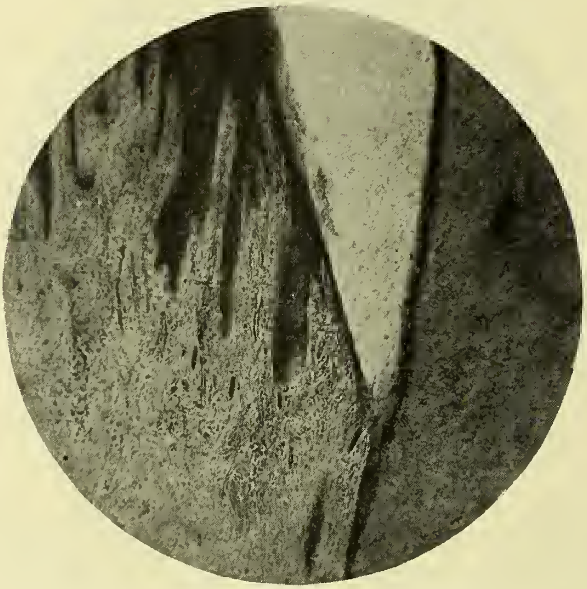


FIG. 119.—Gingival crevice. Marginal and cemental gingiva to the left, showing thin epithetial covering and underlying connective tissue. Dentin covered by cementum to the right. (Courtesy of Dr. Harold K. Box.)

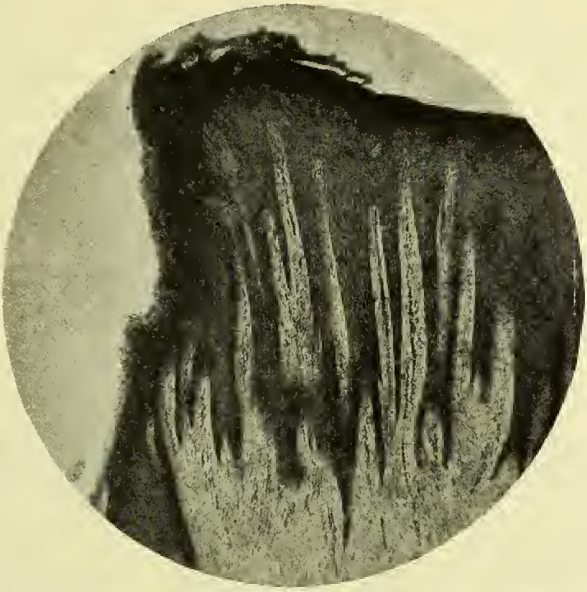


FIG. 120.—Marginal gingiva showing thick epithelial covering. Long finger-like extensions are connective tissue papillae. (Courtesy of Dr. Harold K. Box.)

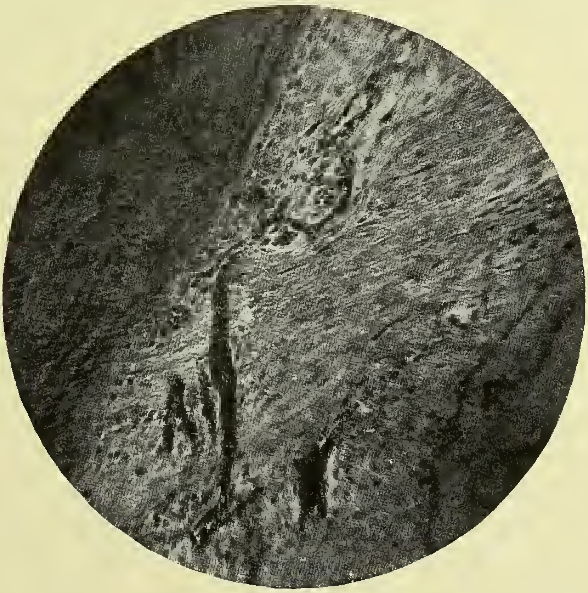


FIG. 121.—Blood vessel in pericementum. Cementum to the left. (Courtesy of Dr. Harold K. Box.)

processes may be prevented is rapidly becoming the most important branch of medical and dental practice. If it is true, as Washington has said that "Knowledge is in every country the surest basis of public happiness," then it must be recognized that a large part of the future public happiness of the nation and the world at large rests in the hands of the medical and dental professions, for happiness and health must go hand in hand, and the maintenance of health depends on a knowledge of methods of disease prevention.

Increasing knowledge of prevention further emphasizes the importance of dentistry as a health service equivalent to an oral specialty of medicine. Since preventive dentistry is the study and institution of measures designed to prevent disease of the oral tissues—oral hygiene—it must be recognized that it is a branch of general hygiene or sanitary science and not merely a local measure.

ORAL FOCI OF INFECTION

All praise is due the pioneers in the field of prevention, including D. D. Smith, G. V. Black, John S. Marshall, Robin Adair, W. G. Ebersole, Alfred C. Fones, Thaddeus P. Hyatt, Paul R. Stillman, John O. McCall, and others. However, it must be admitted that, as is frequently the case under similar circumstances, the importance of a clean and healthy mouth in its bearing on the health of the body as a unit was most forcibly brought to the attention of the profession from outside sources, through the memorable indictment of Doctor William Hunter[1] of England in which a severe arraignment, particularly of so-called "American Dentistry" was made. Doctor Hunter claimed that many dental restorations, such as crowns, bridges, and fillings, concealed the presence of underlying septic material (oral sepsis), which entered the body by way of the blood streams and lymphatics and produced grave systemic disturbances in other parts. He said "The worst cases of anemia, gastritis, colitis, of obscure fevers of unknown origin, of nervous disturbances of all kinds, ranging from mental depression up to actual lesions of the cord, of chronic rheumatic affections, of kidney disease, are those which owe their origin to or are gravely complicated by the oral sepsis produced in private patients by these gold traps of sepsis. Time and again I have traced the very first onset of the whole trouble of which they complained to a period within a month or two of their insertion. There is no rank of society free from the fatal effects on health of this surgical malpractice. This type of poor dental work conserves the sepsis which it produces by the gold work it places, over and around the teeth, by the satisfaction that it gives the patients, by the pride which the dentist responsible for it feels in his "high-class American work," and by his inability or unwillingness to recognize the septic effects which it produces. The medical ill-effects of this septic surgery are to be seen every day in those who are the victims of this gilded dentistry in their dirty-gray, sallow, pale, wax-like complexions, and in the chronic dyspepsia, intestinal disorders, ill-health, anemias and nervous complaints from which they suffer. In no class of patients and in no country are these, in my observation, more common then among Americans and in America, the original home of this class of work." Although previous to this time many other writers in both the dental and medical professions had called attention to the same thing, the composite mind of the profession was not then ripe to receive the message and the indictment of Hunter arrived at the proper psychological moment. An early article of similar import was written by Doctor R. J. Porre[2] of Cincinnati, Ohio, and another by the author,[3] shortly after his graduation; but these, together with others, received no particular recognition.

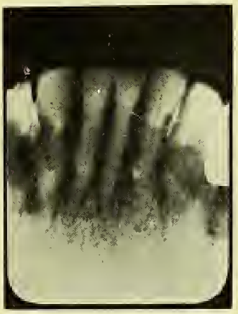


Fig. 122.—Marked periodontoclasia.

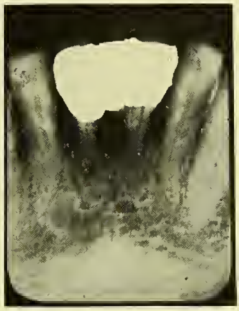


Fig. 123.—Marked periodontoclasia.

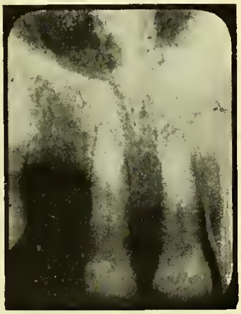


Fig. 124.—Marked alveolar absorption. Nasal cavity.

The criticisms of Hunter aroused a storm of protest and resentment, the profession at first believing them unfounded and unjust. However, as a result and largely as a defensive measure, many dental investigators, among whom may be mentioned Weston A. Price and Thomas B. Hartzell, began work on the question. Members of the medical profession, particularly E. C. Rosenow, Frank Billings and C. H. Mayo also became interested, with the result that today the importance of oral foci of infection in their bearing on the general health of the individual is fully realized by both the medical and dental professions. Both of these professions now recognize the importance of continued investigations of the tissue reactions of the body *as a unit* in their bearing on the advancement of knowledge of further preventive measures necessary to accomplish results.

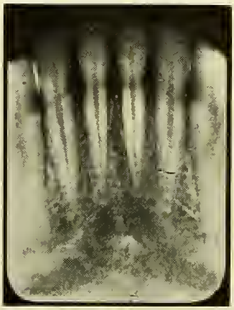


FIG. 125.—Slight alveolar crest absorption.

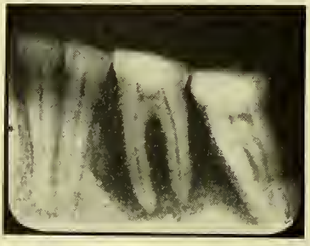


FIG. 126.—Great alveolar absorption.

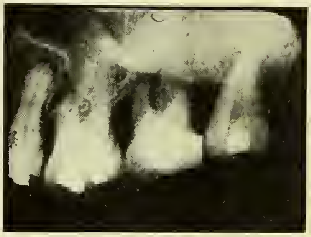


FIG. 127.—Extensive periodontoclasia. Foreshortening.

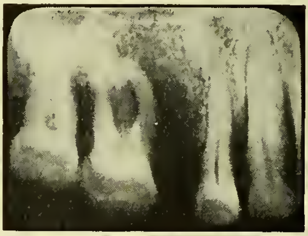


FIG. 128.—Pronounced alveolar destruction.

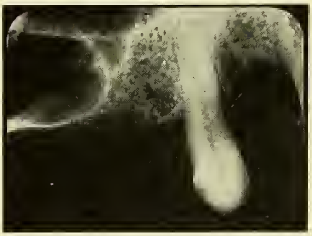


FIG. 129.—Alveolar absorption around cuspid. Large dark area is antrum.

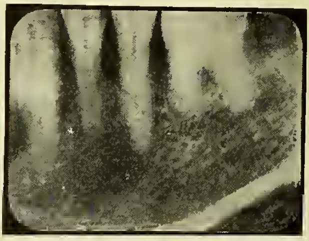


FIG. 130.—Alveolar absorption. Dark area below and between bicuspids is mental foramen.

Metastatic Involvements.—Our present acceptation of the term "preventive dentistry" involves (1) the application of true preventive measures and also (2) the application of certain corrective procedures. Up to recent times both of these have been quite largely of a *local* character. The fallacy of this limited conception of the scope of preventive dentistry is now apparent and we are beginning to realize that the preventive dentistry of the future must involve the application of physiologic, metabolic, dietary and other general therapeutic considerations, as well as local procedures—a true health service. The importance of this broader conception of the scope of oral hygiene is apparent when one realizes that the prevention of mouth disease prevents the inception of metastatic disease of other bodily structures, via the blood and lymph streams as well as by continuity and contiguity of tissue.

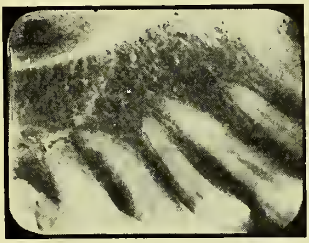


FIG. 131.—Marked periodontoclasia.

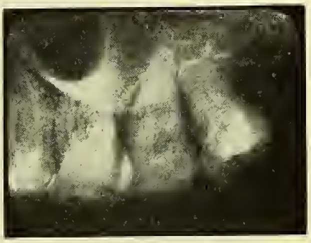


FIG. 132.—Marked alveolar destruction.

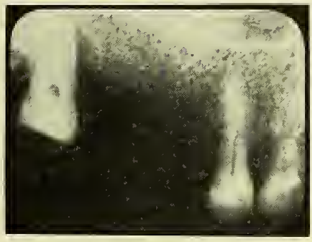


FIG. 133.—Alveolar absorption.

Special attention has been previously called in this work to the close anatomic, physiologic and pathologic relationships existing between the teeth and supporting structures and all other parts of the body. Infection surrounding the roots of the teeth may, and frequently does, extend by way of the vascular and lymphatic systems, as well as by continuity of tissue, to closely associated or far distant parts. As a result, many very grave systemic disorders, either of a vague or definitely manifested nature are produced.

Certain micro-organisms, located in a root canal or in the periapical tissues may be of a harmless nature under the conditions in which they are placed. However, according to Hartzell and Rosenau, if they succeed in entering the blood and lymph streams and are transmitted to other tissues, they may, in their new environment, change their form and characteristics (transmutation) and be productive of great harm. A streptococcus from the tonsil or an alveolar abscess, may, under suitable cultural conditions, change to a pneumococcus, and, if it reach the lung, be productive of pneumonia; or if it reach some joint of the body, may cause arthritis deformans (rheumatism); or in other cases, the same micro-organism may locate in the valves of the heart, be transformed under its new environment into the streptococcus viridans and result in a heart lesion; under other conditions it may travel to the inner coat of the stomach and produce an ulcer of that organ. Under similar conditions, bacilli may be changed to spirilla, and other types of germs may take unto themselves entirely different forms and activities. Harmless bacteria are thus seen to be frequently capable of producing great harm under changed environment, and the opposite result may also occur, viz. harmful species may lose their virulence under different cultural conditions. In septic diseases occurring in the apical space, pus-forming micro-organisms are usually present, which, traveling to distant parts, may, under the changed conditions in which they are placed either lose their virulence or be stimulated to increased activities.

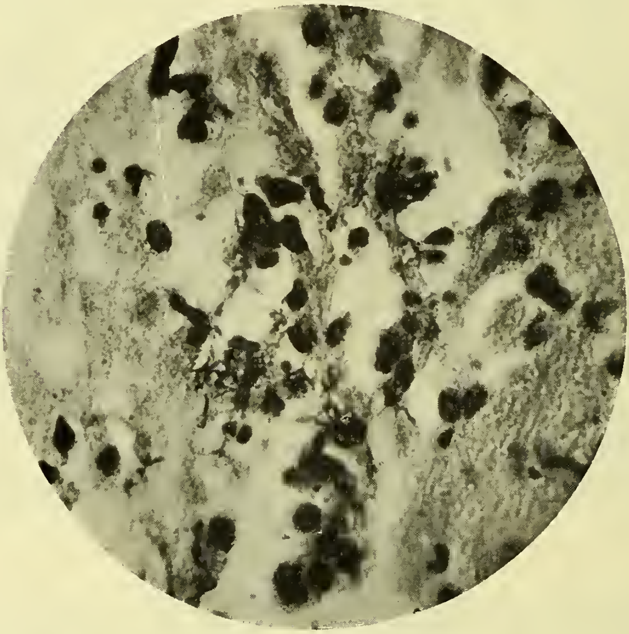


FIG. 134.—Bacteria in ulcer at border of a periodontal pocket. (Courtesy of Dr. Harold K. Box.)

The normal resistive power of the tissues involved, in addition to other factors concerned, will undoubtedly have a definite influence on the result produced.

The following disturbances may result from focal infections located in or about the teeth.

1. Affections of the muscles (myositis).
2. Affections of the joints (arthritis and synovitis).
3. Affections of the blood (septic anemia, endocarditis, and pleurisy).
4. Affections of the glands (lymphadenitis).
5. Affections of the nerves (toxic neuritis and degenerations).

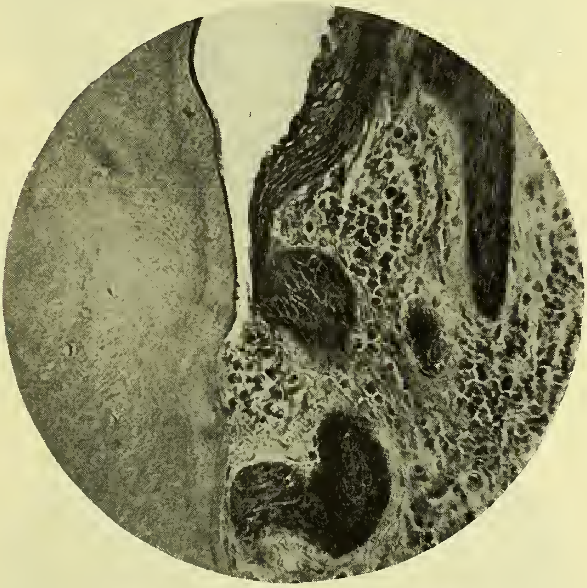


FIG. 135.—First stage in the evolution of a periodontal pus pocket. Faulty junction of crevicular epithelium with the tooth, bacterial invasion and inflammation of underlying tissue shown. (Courtesy of Dr. Harold K. Box.)

6. Affections of the excretory organs (skin rashes and nephritis).
7. Affections of the intestinal tract (septic gastritis, enteritis, cholitis, cholecystitis and appendicitis).

In many instances systemic infections of this nature are easily recognized, diagnosed by the physician and traced to infections about the teeth as causative agents, but perhaps just as frequently the constitutional disturbance is of a very vague nature without markedly definite manifestations. Some of the vague symptoms observable in these cases are anemia, pallid or pasty complexion, general malaise, loss of

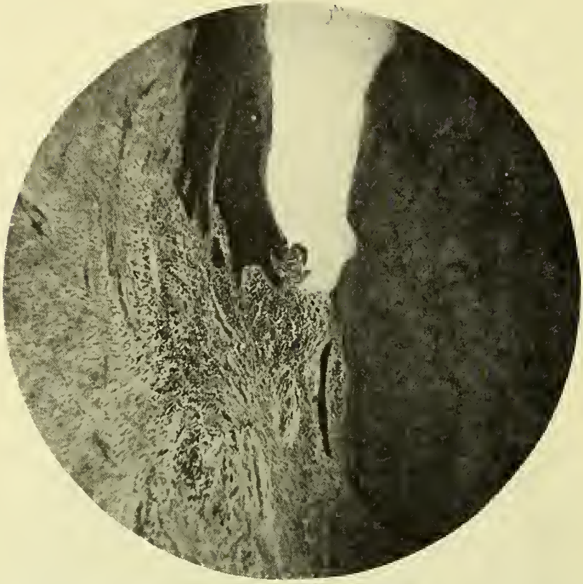


FIG. 136.—Second stage in pocket formation. Inflammatory reaction increased, loss of epithelial covering and beginning ulceration at bottom of pocket. (Courtesy of Dr. Harold K. Box.)

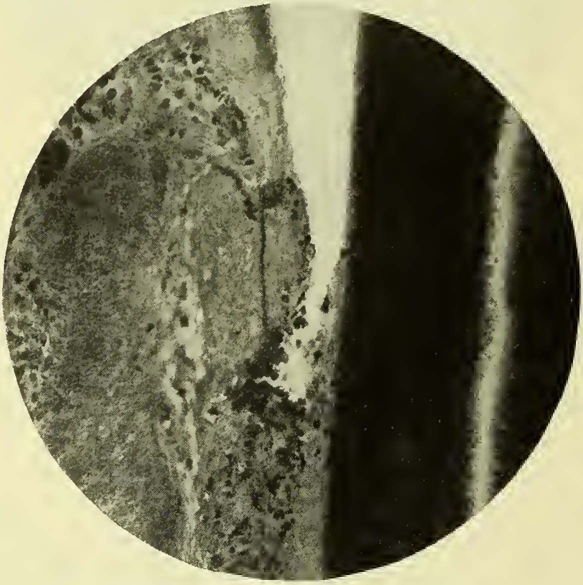


FIG. 137.—Third stage of pocket formation. Well marked ulceration, inflammatory reaction surrounding it and denudation of cementum except at bottom of pocket. (Courtesy of Dr. Harold K. Box.)

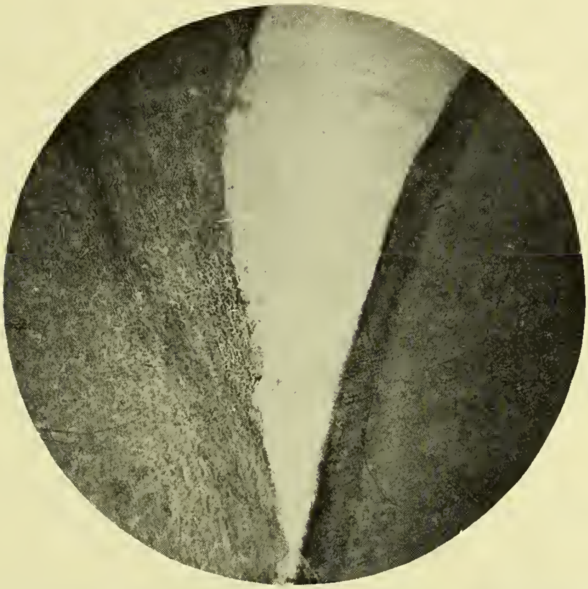


FIG. 138.—Fourth stage in periodontal pocket formation. Loss of tissue, denudation of cementum and ulceration of large surface. (Courtesy of Dr. Harold K. Box.)

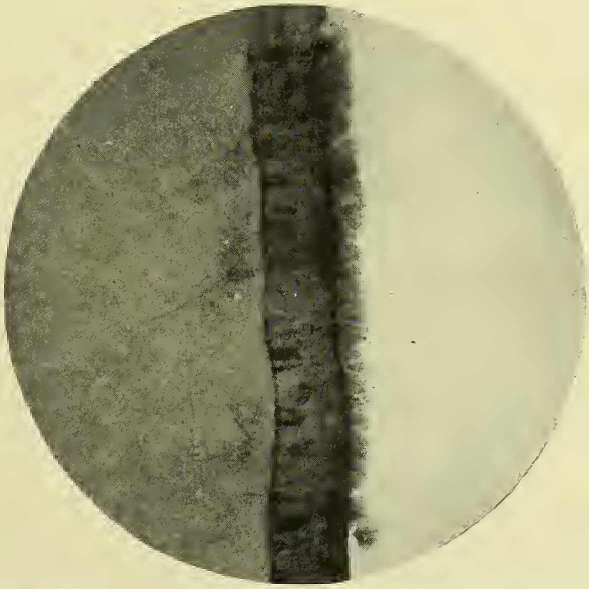


FIG. 139.—Bacteria in pericemental pocket on surface of cementum. Bacteria are penetrating cementum (dark central area) and dentin (area shown to left). (Courtesy of Dr. Harold K. Box.)

appetite, debility, night sweats, loss of weight, low fever (100°F.) or sub-normal temperature. Many cases of this kind have been cured by the removal of infections in the mouth, either through sterilization and filling of root canals, treatment of chronic alveolar abscesses, extraction of the affected teeth, removal of tonsils, eradication of pyorrhea pockets, treatment of antral disease, abandonment of faultily constructed crowns and bridges and other sources of infection.

Health Relationships.—It is then highly important for the dentist to fully realize the great significance of the bearing which his operations may have on the health and even the life of his patient. It is, however, equally important for him to recognize the fact that the above mentioned disturbances may, in many instances, have no connection whatever with oral conditions, but may be due to entirely different causes, viz., the focus of infection producing the disturbance may be situated in an entirely different part of the body. The significance of conditions of this nature was not fully appreciated by either the medical or the dental profession until recently. A full realization of their import has often resulted in the adoption of extremely radical measures for their relief by many men in both professions, with the result that thousands of teeth have been needlessly and ruthlessly sacrificed during the past decade through the extraction operation. The radical element in the medical profession has been especially guilty in this regard, referring patients to the exodontist whenever they were unable to discover other causes for systemic disturbances, and not realizing or recognizing the full importance of the necessity for the retention of the teeth for preservation of the continuity of the arch. A similar class of dental practitioners, prone to enthusiastically subscribe to new fads, has been guilty, with the result that great harm has been done. However, it would seem that a normal, sane attitude is about to be reached by both professions in regard to questions of this nature.

The solution of the problem lies in the establishment of closer affiliations between the two professions, and a closer study, on the part of both, of the diagnostic, pathologic and clinical relationships of these disturbances. An imperfectly filled pulpless tooth or a partially healed infection at the apex of the tooth is always likely to be suddenly transformed into an active source of systemic infection, if the resistive powers of the body be low, from any cause, and especially so if the normal resistance be temporarily or permanently lower from some systemic disturbance arising after the dental operation has been performed.

Operations of this nature, even if they are believed to be well-nigh perfect as revealed by the X-ray, may suddenly give trouble and become active sources of infection in constitutional disturbances, lowering the resistance of the tissue cells of the patient, since, as is well known, a single micro-organism left in position and suddenly springing into activity may multiply at a rapid rate and transform the apparently successful operation into a local focus of infection which may become a menace.

Elective Localization.—Edward C. Rosenow,[4] Weston A. Price[5] and others have made frequent reports on the property of elective localization for certain tissues of certain germs, particularly the streptococcus viridans, in cases of focal infection. By isolating bacterial cultures from infected tonsils, peridental tissues, or from the systemic lesions of patients suffering with heart or kidney or other lesions, supposedly due to the tonsil, peridental or other infections, they have, by injection of these cultures into the lower animals succeeded in producing similar disturbances in the same tissues in the injected animal. These are really very valuable experiments, since they are the chief proof available at present of the theory of focal infection and the possibility of the production of systemic disturbances from oral and other septic conditions. Figure 140 reveals the results of the localization in animals of streptococci from focal infections, obtained by Rosenow.

Doctor Weston A. Price reports the successful results of numerous experiments in elective localization on rabbits and other animals and the reader is referred to his monumental work on "Focal Infections" for more detailed information. Doctor Price[6] states that "Dental infections may or may not contain organisms with a specific elective localization quality for certain tissues of the body. When they do so it is generally because the part is suffering or has previously suffered from an acute process in that tissue, which acute process frequently, entirely and permanently disappears with the removal of the focus of infection. Defense and absence of defense to streptococcal infection as an organ and tissue quality seems definitely to be related to inheritance and, as such, obeys the laws of mendelain characteristics."

HISTORY OF ORAL HYGIENE CAMPAIGN

In view of the realization of the importance of a clean healthy mouth in its bearing on general systemic disturbances, the dental profession has for a number of years been busily engaged in an oral hygiene campaign for the dissemination of knowledge in this direction and it has had

TABLE 3.—LOCALIZATION IN ANIMALS OF STREPTOCOCCI FROM FOCI OF INFECTION IN PATIENTS SUFFERING FROM SYSTEMIC DISEASE

Source of Cultures	Cases	Animals		Cases Yielding Positive Results	Percentage of Animals that Developed Lesions in:												Cultures from			
																	Specific Lesion		Blood	
		Injected	Died		Skin	Muscles	Joint	Intestines	Stomach or Duodenum	Gallbladder	Kidneys	Lungs	Myocardium	Endocardium	Pancreas	Nerves	No.	Positive Percentage	No.	Positive Percentage
Chronic arthritis	17	41	11	15	0	**46**	**66**	0	15	0	5	5	5	7	0	0	27	70	38	58
Ulcer of stomach or duodenum	40	90	18	34	0	7	2	3	**61**	0	3	2	7	1	0	0	10	80	69	32
Cholecystitis	21	57	28	18	0	4	0	9	22	**65**	11	4	12	0	11	0	42	67	54	72
Myositis	3	7	2	2	0	**71**	**29**	0	0	0	14	0	0	14	0	14			6	17
Neuritis	6	26	6	5	0	12	0	0	0	0	0	0	8	8	0	**58**			10	60
Pyelonephritis	5	15	2	4	0	20	14	0	0	0	**80**	0	7	7	0	0	6	67	10	20
Endocarditis	3	10	1	2	0	10	0	0	30	0	30	10	10	**50**	0	0	1	1	10	40
Erythema nodosum	1	12	0	1	**75**	**67**	42	0	0	0	17	0	0	0	0	0			12	0
Herpes zoster	11	31	13	6	**35**	13	6	0	0	0	0	0	0	0	0	0			29	38
Diabetes	8	29	11	6	0	0	7	0	7	0	3	0	0	0	**48**	0	11	37	21	33
Chorea	6	19	6	3	0	26	26	0	0	0	5	0	21	**47**	0	0	5	60	18	33
Total	121	337	98 29%	95 78%													102	66	277	43
Miscellaneous	62	129	39 30%		1	9	6	0	4	0	2	3	3	5	0	2			77	32
Results exclusive of specific strains					0	9	5	2	8	0	6	2	7	3	2	0				

FIG. 140.—Tabulation of Edward C. Rosenow. (Courtesy of The Journal of the American Dental Association.)

the support of the medical profession in the broadcasting of its educational propaganda.

Articles in the newspapers and magazines, fostered by dentists, physicians, and organized bodies, such as the American Dental Association, the American Academy of Periodontology and other organizations have been and still are productive of increased knowledge and interest on the part of the laity. The organization of the Bureau of Public Relations under the auspices of the American Dental Association is, through the monthly publication of valuable information on dental health topics, an important forward step toward increased knowledge of measures for the advancement of preventive dentistry. The literature of the various dentifrice and tooth brush manufacturers, although often unscientific and misleading as to the proper functions of these articles, has undoubtedly assisted greatly in focusing the attention of the public on the importance of regular oral hygienic measures. The talks of dentists at the chair to their patients, in lectures before public gatherings and over the radio cannot be of too frequent occurrence, and greater efforts should be manifested in this direction. The importance of the proper and regular use of the brush, the floss and the dentifrice, adequate habits of mastication and regular visits to the dentist cannot be too greatly stressed. The establishment of periodic examinations of the mouth, of the tooth brush drill and of dental clinics in the public schools has been productive of great good for the younger generation. The first scientific and practical test was established in the Marion School in Cleveland in 1910 under the supervision of Doctor W. G. Ebersole, acting for the Oral Hygiene Committee of the National Dental Associaton, the Oral Hygiene Association of the Ohio State Dental Society, and the Cleveland Dental Society, and of Miss Cordelia L. O'Neill, principal of the school, acting for the Board of Education. Chicago and Ann Arbor, Michigan were among the first cities to have inspection of the mouths of school children, while Cambridge, Massachusettes had the first dental school clinic. This idea has grown to immense proportions and has spread until there are few public schools in the United States where either some form of dental knowledge is not disseminated, where periodic examination of the mouths are not made or where prophylactic work and plastic fillings are not inserted. Dental clinics are gradually being established in hospitals and schools and commercial concerns throughout the country. New York City alone boasts one hundred and fifty-two dental clinics with five hundred and sixteen operating chairs.

Since the establishment of the first commercial dental clinic in the Metropolitan Life Insurance Company under the supervision of Doctor Thaddeus P. Hyatt, growth of this type of service has reached enormous proportions. Cooperation of boards of health, physicians, and dental colleges providing service for examination, advice, prevention or correction, is making itself felt. In Connecticut, the enthusiastic work over a long period of years of Doctor A. C. Fones is bearing fruit and over 50% of the towns in that state have maintained dental programs for children. Many of the state and city Boards of Health are being assisted in the dissemination of dental knowledge by Dental Advisory Boards and closer cooperation is constantly being established between the dental and medical professions in this regard. Increasing attention to prophylactic and preventive dental measures is being given by hospital staffs, and in many of the important hospitals the work of dental internes is considered of great importance. In some of the hospitals, special dental carts carrying electric engines, instruments and other accessories have been devised in order that bedside dental service may be rendered. In others, nurses are trained in oral hygienic measures, patients are taught the use of brush, dentifrice and floss and, where unable to use them, are given the service by the nurse. In some schools community experiments are in progress, history charts, photographs, models, etc. being recorded of oral hygiene, dietary and other findings, which when completed will be very valuable. In some of the dental schools children's clinics have been established and others are in process of organization. At the New York University College of Dentistry a special preventive dentistry clinic for children has been organized for several years, and experiments on very young children, with control groups, are being carried out with the cooperation of the members of the staffs of the medical and dental schools over long periods. From these, it is believed, valuable information will be obtained in dietary measures, prophylactic odontotomy, arch predetermination, rate of growth, and other affiliated subjects.

The work of the dental hygienist deserves special mention and commendation in this brief outline of the history of the oral hygiene movement. The valuable service which these young women are rendering as teachers, lecturers, leaders, organizers, prophylactic specialists and assistants is so important that it cannot be evaluated. They are usually self-sacrificing, enthusiastic, efficient and humanitarian in their ideals and have fully justified the establishment of special schools and courses for their training.

The first course for the training of dental hygienists was organized in the Spring of 1910 and taught at the Ohio College of Dental Surgery in Cincinnati, Ohio, beginning with the session of 1910–1911. Long before that time Dr. Cyrus M. Wright, a distinguished dentist and Professor of Physiology in this school, had advocated personally and in his writings the importance of training women for such duties. His strong personality and forceful advocacy of this idea, in time impressed themselves on the minds of the authorities of the School, and finally it was decided to give his plan a trial.

The author of this book, at that time Superintendent of the School and a strong believer in the possibilities involved, formulated, in conference with Dr. Wright, the curriculum, submitted it to Dr. Henry T. Smith, the Dean, and to the faculty. With a few modifications this curriculum was approved and announcement of the proposed course was made in the catalogue of the College. The first class was organized in the Fall of 1910 and graduated in the Spring of 1911. With subsequent increases in enrollment, Dr. Flora N. Haag was later appointed Supervisor of the course for Dental Nurses, as it was then termed. She served faithfully and efficiently in this capacity until her appointment to a teaching position in Western Reserve University in 1918.

In 1920, owing to the financial stresses of the World War, the doors of the Ohio College of Dental Surgery, the second oldest dental school in the world, were closed forever. In this old school were graduated the first woman dentist and the first dental hygienist. The second course for dental hygienists was opened by Dr. Alfred C. Fones of Bridgeport, Connecticut, in November, 1913.

The successful work of the Forsyth Dental Infirmary in Boston and the Eastman Dental Dispensary in Rochester, under endowments of two public spirited humanitarians, has demonstrated the need for many more similar institutions where the gospel of oral hygiene may be preached and practiced for the benefit of coming generations. The establishment of similar institutions in London, Rome, Vienna and other cities, and of the Gugenheim Foundation in New York City is an evidence of the increasing interest in preventive dentistry. In view of the interest manifested by the officials of the United States Government in forest conservation, prevention of tuberculosis and other diseases in cattle, it is felt that through education, the government at Washington will undoubtedly in time interest itself more profoundly in the preservation of human health and prevention of oral and other diseases. Some day in the not distant future the nation will elect a president who will have the vision to form a more efficient Bureau of Public Health whose chief function and duty will be to conserve the health of the nation. When this great forward movement is consummated, the dental profession will undoubtedly be represented and adequate means will be at hand to advance the cause of preventive dentistry.* In the words of the prophet "Where there is no vision the people perish." A wise ruler once said "The health of the people is the supreme law." Human lips never uttered a more profound truth, for the idea thus expressed lies at the foundation of the material, intellectual and spiritual greatness of the nations of the world.

BIOLOGIC CONSIDERATIONS

It is now recognized that the mouth is constantly teeming with micro-organisms, pathogenic and non-pathogenic, in health and disease, living in symbiotic relationship to each other. The process of reproduction in bacteria is a very rapid one. The process of segmentation[7] or cell division in certain cocci supposedly requires twenty minutes and it has been estimated that division at the rate of one each hour would produce from one coccus 16,000,000 progeny in 24 hours, 281,000,000,000 in 48 hours and 46,000,000,000,000 at the end of three days. Miller, in his Micro-organisms of the Human Mouth estimated that in a certain unclean mouth there were present 1,140,000,000 micro-organisms.

Under normal conditions, the oral bacterial flora leads a low grade saphrophytic existence; but under poor hygienic conditions and in the presence of food debris, fermentations and putrefactions are readily set up and this flora is markedly increased. Certain types of germs under these circumstances may react with a high degree of virulence and the entire picture is changed, many of them being then capable of attacking the hard and soft tissues of the mouth and producing harmful influences upon them.

Three distinct types of these germs may be noted, viz., *first*—the aciduric type, producing fermentation of carbohydrate food debris; *second*—the proteolytic type, acting on the protein material; and *third*—certain other types, such as the pneumococcus and the diptheria bacillus. The first type mentioned is the active or exciting cause of caries; the second is also concerned in caries of the dentin, acting on the organic constituents, but is of especial interest in this discussion because of its toxic properties and its irritating effect on the gingiva and oral mucosa; while the third type, which produces no particular action on the oral tissues is still undoubtedly multiplied in unhygienic conditions of the mouth and is carried to other parts where harmful results may arise, depending on the tissue or cell resistance of these parts.

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* Since writing the above a Child Health Conference was called and a new National Institute of Health has been organized.

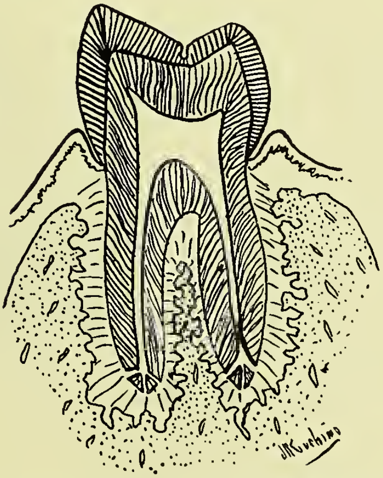


FIG. 141.—Lower molar showing protective enamel covering, normal gingival crevice and periodontal tissues. (Diagrammatic.)

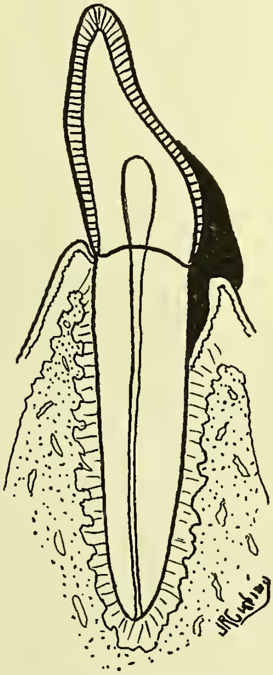


FIG. 142.—Lower incisor showing deposit of calculus, pocket formation and destruction of peridental tissue on lingual aspect.

The type of micro-organisms predominating in the mouth is regulated to quite a degree by the character of the food habits of the individual, carbo-hydrate media stimulating the multiplication of the aciduric type, while a protein diet produces an excess of the proteolytic type. The character of the diet and the metabolic processes concerned in its assimilation and elimination will also affect the bacterial flora through regulation of the character of the oral fluids, thus modifying the type of organisms predominating. Symbiotic relationships are also concerned.

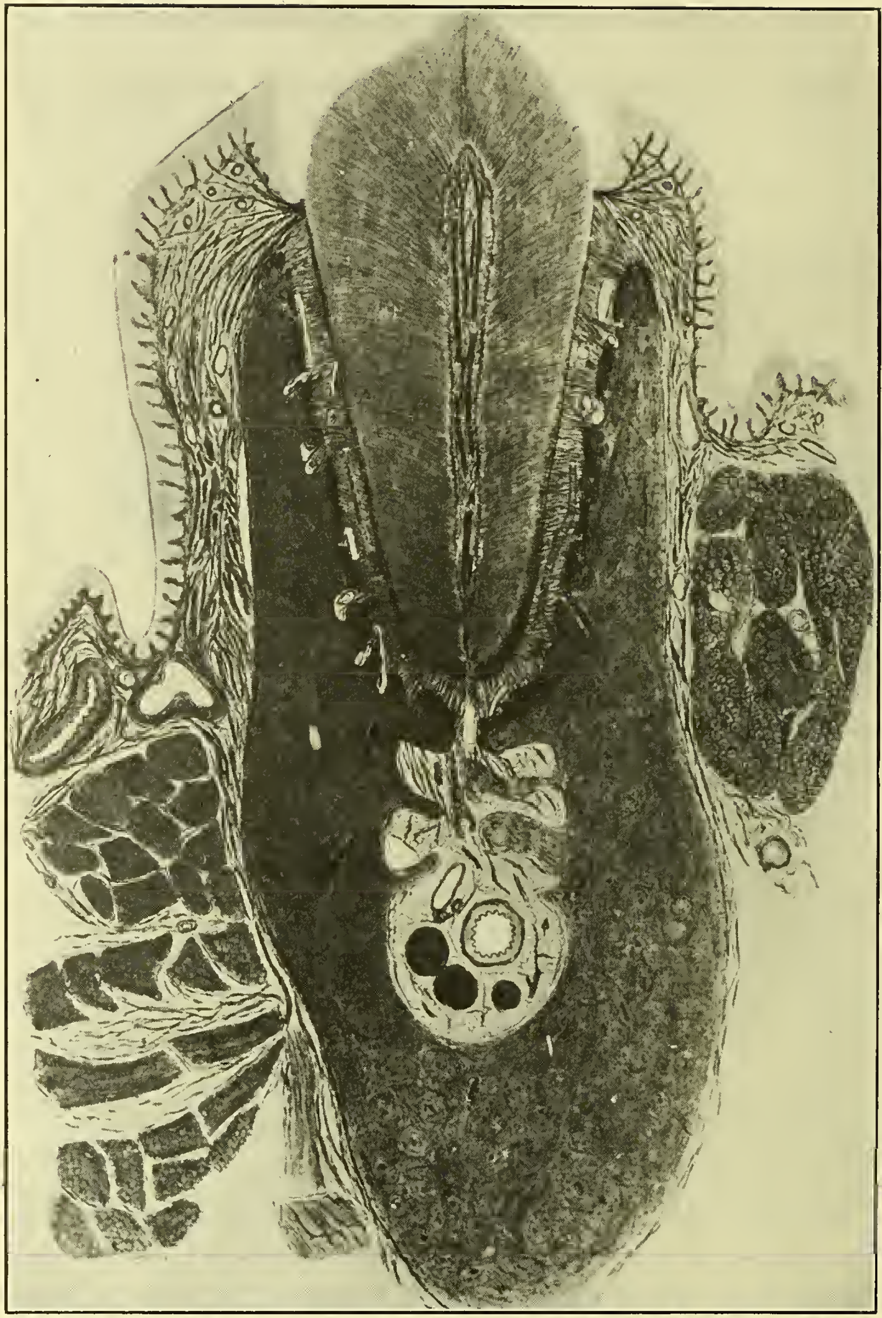


FIG. 143.—Sketch from an anatomical specimen, drawn by Dr. S. F. Gunter. Enamel decalcified and removed. The gingival crevice, contents of the inferior dental canal, salivary glands, arteries, veins, nerves, lymphatics, muscles, bone, dentin, pulp and peridental tissues are shown.

Avenues of Entrance.—The two principal avenues of entrance of these micro-organisms into the oral tissues are through carious and defective tooth structure and through the gingival crevice. The healthy mucous membrane of the mouth offers an effective barrier against the entrance of germs into the deeper underlying tissues. The gingivae are the most vulnerable tissues in this regard, due to the fact that they present an end-circulation and are particularly subject to irritation, inflammation and infection. Most of the pathologic disturbances of the soft tissues of the mouth begin at the free gingiva as a result of faulty oral hygienic measures, accumulation of food debris, trauma, deposits of calculus, imperfectly constructed crowns, fillings, bridges and other appliances. As a result, these tissues become inflamed, swollen and puffy and the purse-like flap of the gingival crevice which normally hugs the neck of the tooth tightly and offers firm resistance to the entrance of infective germs, is opened, its normal tone is lost and it falls away from the tooth, thus offering an entrance for infection. The surrounding and underlying tissues also become inflamed and less able to combat the invading army with the result that deep penetration occurs into the alveolar bony structures. If the resulting infection be of a purulent

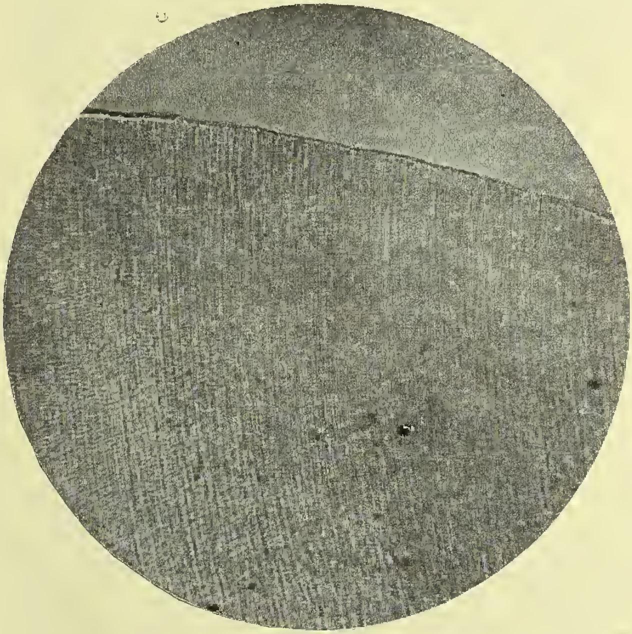


FIG. 144.—Enamel rods running in parallel direction. Nasmyth's membrane on the surface Low power. (Courtesy of Dr. John B. Stein.)

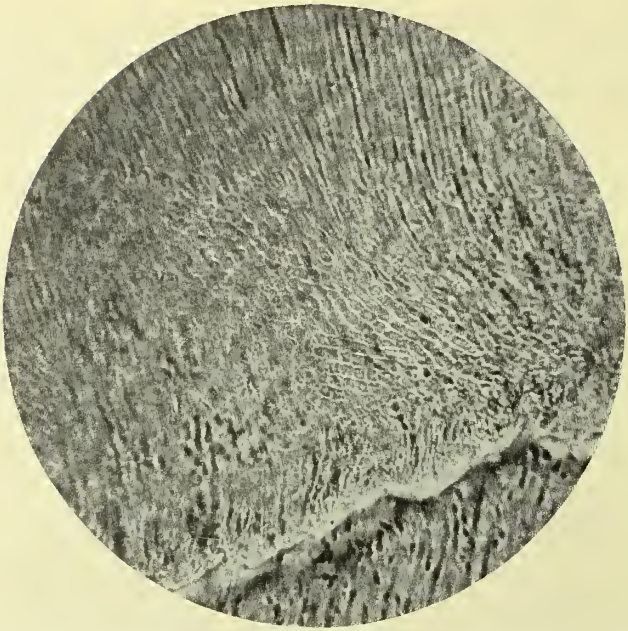


FIG. 145.—Dento-enamel junction. Enamel above, dentin below. Enamel rods shown in transverse, oblique and longitudinal sections. Dentinal tubules in transverse and longitudinal section. (Courtesy of Dr. John B. Stein.)

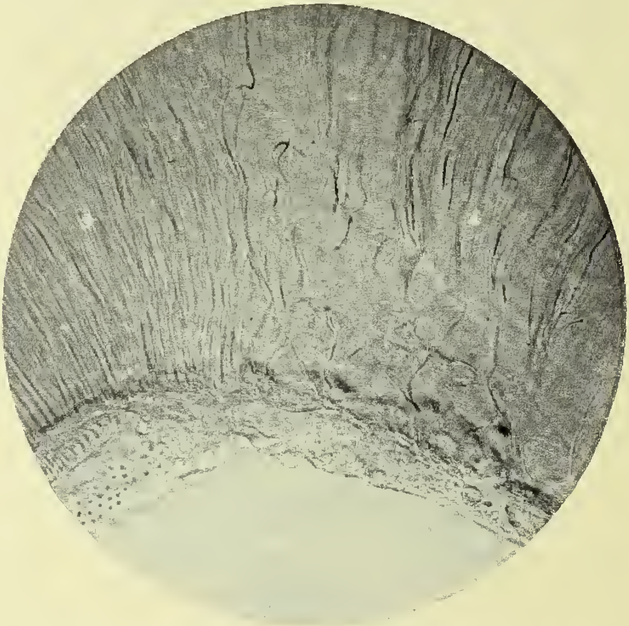


FIG. 146.—Dentin above, pulp chamber below. Adventitious dentin, lining pulp chamber, shows tubules in transverse section. (Courtesy of Dr. John B. Stein.)

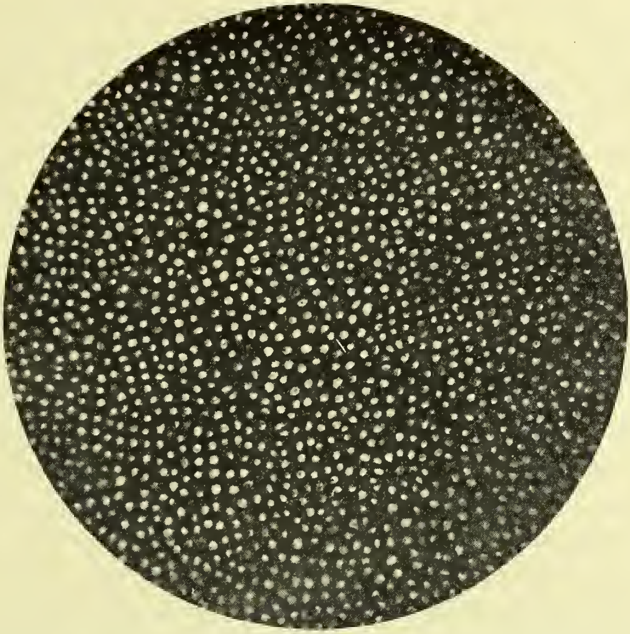


FIG. 147.—Low power picture of the dentinal tubules as seen from the pulp chamber Transverse section. (Courtesy of Dr. John B. Stein.)

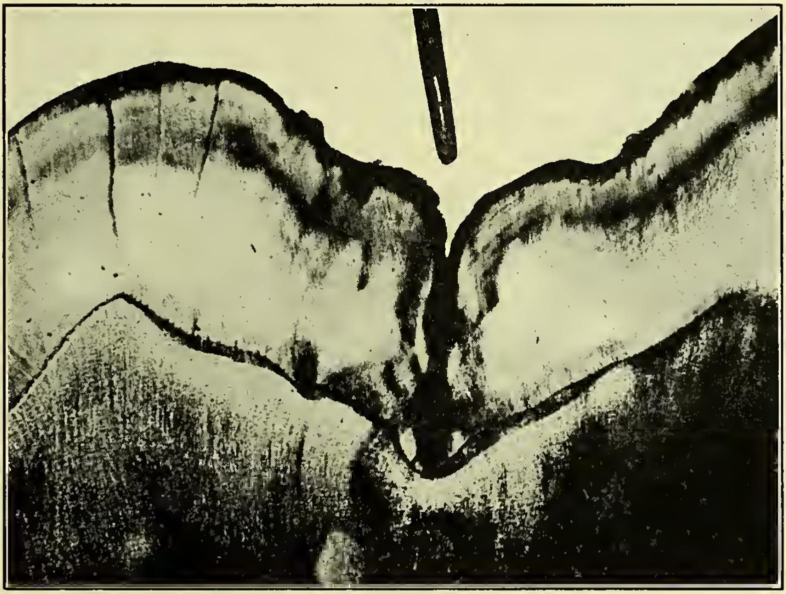


Fig. 148.—Defective and carious occlusal fissure. Relative size of a toothbrush bristle shown. (Courtesy of Dr. Charles F. Bödecker and the Publishers of Dental Items of Interest.)

type, due to the action of hemolytic, pus-forming, micro-organisms, such as the streptococcus pyogenes, staphylococcus pyogenes aureus and citreus and bacillus pyoceaneus, acute superficial ulcerations and deeper peridental affections, with pus formation and deep pockets characteristic of pericementoclasia (pyorrhea alveolaris), usually occur. If the germs concerned are of the non-purulent type, various strains of streptococci, notably streptococcus viridans are concerned, and the sub-acute or chronic forms of gingivitis and pericementitis arise in which pus-formation is absent, the condition being more of the degenerative, deeply penetrating type.

The other principal avenue of entrance of infection to the deeper tissues is through defective pits and fissures on occlusal, buccal and lingual surfaces of the teeth and *via* carious cavities (Fig. 148). These result from the formation of the bacterial plaque and fermentation of carbo-hydrate food masses in these areas through the action of the bacillus acidophilus and other acid forming micro-organisms. The tissues of the pulp are invaded and the pus-forming germs mentioned in connection with the peridental infection may gain entrance via the vascular circulation of the pulp to the periapical tissues with the resultant formation of an alveolar abscess. Or in other cases, the streptococcus viridans and other streptococci may enter through the same avenues and produce a granuloma.

In either case, the systemic manifestations of the absorption of toxic and infective products may arise as a result of infection of other tissues of the body. It was formerly believed that the acute local manifestations of pus-forming micro-organisms were the most dangerous, but with an increasing knowledge of oral sepsis and the method of production of foci of infection in distant parts it is now well understood that the sub-acute and chronic degenerative types are the dangerous ones and the most frequent causes of marked constitutional disturbance from oral foci of infection.

It may now be perceived that if measures could be devised to successfully protect and close the two main avenues of entrance of infective germs to the underlying tissues, namely, by way of (1) *the gingiva or of* (2) *the enamel, the dangers of oral sepsis and of systemic disease from oral sources would be largely eliminated.*

TISSUE RESISTANCE AND SUSCEPTIBILITY

When infective organisms have succeeded in penetrating the normal protective coverings, the mucous membrane or the enamel and dentin of the tooth, and enter the subjacent tissues they meet there a second line of defense, consisting of all the resistive reactions of the tissue cells, such as phagocytosis, bacteriolysis, antitoxins, granulation tissue formation and similar defenses. If granulation tissue is formed, connective tissue fibers later develop and the organisms are partially or completely confined to the locality. Owing to the existence of a free blood supply containing lymphocytes and leukocytes, forming as a result of chemotaxis, or of the fibrous sac, the organisms may be effectually walled off at the root end. However, there is always a possibility of absorption of the germs or their toxins into the general blood stream, which frequently occurs, its frequency depending on the resistive powers of the cells of the host to infective processes. If the general vital forces of the individual are high, the resistive powers of the defensive cell mechanism may be great and, vice versa, if the resistive forces are low, the response of the cells may be inadequate and grave systemic results may arise. Also the resistive powers of individuals vary to varying types of micro-organisms. The tissue reactions are usually high against the purulent types and low against the non-purulent types. Consequently the latter types of reactions are the most dangerous, because they are most likely to produce grave systemic complications and also because they are frequently masked in character and often unrecognized.

According to Doctor Weston A. Price,[8] human beings do not react similarly in their susceptibility to systemic involvement to dental infections. They, however, may be divided into three groups, namely, those with inherited, those with acquired and those without susceptibility to rheumatic group lesions. Doctor Price further states that susceptibility to dental caries and systemic involvements from dental lesions are proportional both as cause and effect and as related symptoms and also that individuals with marked susceptibility to periodontoclasia have as a group a decreased susceptibility to the rheumatic group lesions during the period of its active development, although in the secondary stages it may contribute to rheumatic group lesions. Pursuing the subject further he states that the systemic manifestations of dental infection may not manifest themselves until the patient is subjected to some overload such as influenza, pregnancy, lactation, malnutrition, exposure, grief, worry, fear, heredity or age.

Bibliography

1. Hunter, Wm.: The role of sepsis and antisepsis in medicine, London Lancet, Jan. 14, 1911; Dental Cosmos, July 1918, p. 585.

2. Porre, R. J.: Chronic pyaemia of dental origin, Trans. 9th Internat. Med. Congress, 1887.
3. McGehee, W. H. O.: Relation of dentistry to general medicine, Virginia Hospital Bulletin, July 1906.
4. Rosenow, E. C.: Elective localization of streptococci, Jour. Amer. Med. Assoc., Nov. 1915, p. 1687.
5. Price, Weston A.: "Dental Infections, Oral and Systemic," vol. I and II, Penton Pub. Co., Cleveland, 1925.
6. Price, Weston A.: "Dental Infections, Oral and Systemic," vol. I, p. 310.
7. Marshall, Jno. S.: "Mouth Hygiene," Lippincott, Philadelphia, p. 8.
8. Price, Weston A.: "Dental Infections, Oral and Systemic," vol. I, p. 628.

Rosenow, E. C.: The relation of dental infections to systemic diseases, Dental Cosmos, May 1917, p. 485.

Rosenow, E. C.: The pathogenesis of focal infections, Jour. Nat. Dent. Assoc., Feb. 1918, p. 113.

Billings, Frank: Focal infection, Jour. Amer. Med. Assoc., Sept. 12, 1914, p. 899.

Mayo, C. H.: Constitutional diseases secondary to local infections, Dental Review, April 1913, p. 281.

Mayo, C. H.: Mouth infection as a source of disease, Dental Summary, Jan. 1915.

Mayo, C. H.: The control of focal infections, Dental Cosmos, Nov. 1918, p. 963.

Hartzell, T. B. and Henrici, A. T.: Report of mouth infection, Research Corps of the Nat. Dent. Assoc., Official Bulletin, Jour. Nat. Dent. Assoc., Oct. 1915, p 48; 1915, p. 333; Nov. 1916, p. 333; May 1917, p. 447.

Rosenow, E. C.: Oral sepsis in its relation to focal infection and elective localization, Jour. Amer. Dent. Assoc., Aug. 1927, p. 1417.

McGehee, W. H. O.: Constitutional treatment of dental diseases, Dental Summary, April 1910.

McGehee, W H. O.: Oral manifestations of constitutional disturbances, American Dentist, Aug. 1915.

Howitt, Beatrice P. and Fleming, W. C.: Quantitative examination of mouth flora, Jour. Dental Research, vol. X, no. I, Feb. 1930, p. 33.

Fones, A. C.: Origin and history of dental hygienist movement, Jour. A. D. A., Dec. 1926, p. 1.

Weinberger, B. W.: Origin of first course for dental hygienists, Dental Survey, Aug. 1936.

CHAPTER IV

PREVENTION OF ORAL DISEASES (*Continued*)

DEVELOPMENTAL AND STRUCTURAL INFLUENCES—NUTRITION AND DIET

DEVELOPMENTAL AND STRUCTURAL CONSIDERATIONS

Many phases of the embryologic development and histologic structure of the teeth are still shrouded in mystery. The reported findings of certain investigators are disputed by others. Many researches are at present in progress, review of which the scope of this work would prohibit. It is hoped that many of these problems will soon be cleared up, since they have an important bearing on preventive, nutritional and dietary, as well as operative procedures.

Most of the conflicting findings concern the minute structure of the enamel and its relationship to the nutritional forces of the body. Another important problem on which a review of the available literature reveals claims and counter-claims is that in regard to the nutrition and minute anatomical relationships of the dentin and cementum.

The question whether metabolic or systemic conditions of the body can affect the enamel has been disputed by Tomes, G. V. Black, Leon Williams, Hopewell-Smith, John Bethune Stein and many others. These investigators claim that the tissue is almost if not entirely inorganic in character and is entirely outside the pale of nutrition. Leon Williams, however, in his later writings seems to change his views in this regard. Many other writers make opposing claims and present beautiful photomicrographs showing what they interpret as nutritional channels and claiming that the enamel is subject throughout life to metabolic changes and is affected by variations in health and vitality of the patient, thus being more subject to caries and other pathologic disturbances in illness or any depleting health influence and less susceptible to these influences when the health and resistive powers are high.

The author has claimed in all of his writings that probably all of the tissues of the teeth including the enamel are subject to some form of nutritional, osmotic, physical or mechanical change and that they are capable of offering vital or some imperfectly understood form of resistance against attacking pathologic influences.

The school of investigators who believe that the resistance of tooth enamel varies with variations of the health of the individual have divided into two groups, one maintaining that this tissue may be calcified or decalcified by osmotic forces from the salivary fluids, the other claiming that circulatory influences from the pulp via the dentinal tubules, having a direct connection with the organic constituents of the enamel, are responsible. Prominent among the first group are H. F. Hawkins and William Ruthrauff and among the latter are Charles F. Bödecker, Theodore Beust and E. W. Fish.

Calcium Metabolism.—The following findings have been established by experiments in vitro or in vivo with reference to calcium metabolism in the teeth:

Michaels.—Found that the saliva has a high acid reserve in immunity and a high alkaline reserve in caries.

J. S. Marshall.—Corroborated Michaels in his findings and established his "Salivary Factor," viz.: when the total alkaline and acid neutralizing power of *resting* saliva does not exceed by 80% the total alkaline and acid neutralizing power of *activated* saliva, the teeth are immune; while there is active caries in mouths in which the percentage exceeds 80%.

C. F. W. Bödecker, Morgenstern, C. F. Bödecker.—Claim that the enamel increases in hardness with age.

Joseph Head.—Found that enamel slightly decalcified by acids can be hardened by the action of saliva, either by a recrystallization or by reuniting with some constituent of the saliva.

H. P. Pickerill.—Claims that enamel hardens with age. It is permeable to stains and fluids, its permeability decreasing with age. Both the enamel and dentin act as dyalizing membranes. Crystalloids pass through while colloids do not. Calcium phosphate is held in solution in the saliva by CO_2 which, not being given off early, the calcium phosphate is dialized into the enamel and deposited, the CO_2 passing back into the saliva.

R. W. Bunting.—Found in hard dense teeth immune to caries a salivary calcium content of .0030 to .0040 grams to 25 cc. of saliva; in soft teeth with caries susceptibility the salivary calcium content was reduced to .0025 grams to 25 cc. as a maximum, while in pregnant women he found that the calcium content varied from .0017 to .0021 grams to 25 cc. of saliva. He also succeeded in calcifying in vitro,

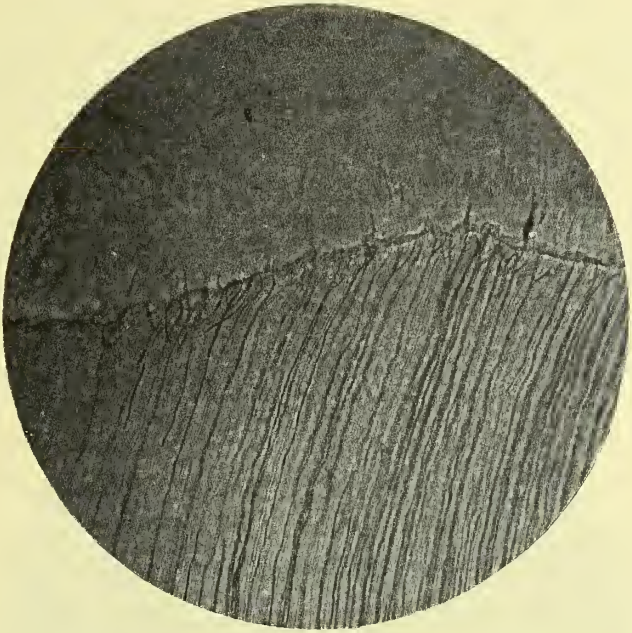


FIG. 149.—Low power picture of the dento-enamel junction. Enamel above, dentin below. (Courtesy of Dr. John B. Stein.)

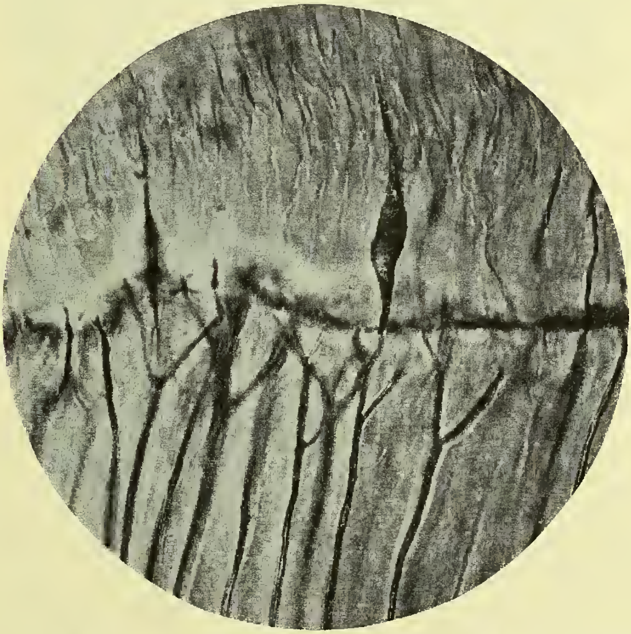


FIG. 150.—Dento-enamel junction. Dentin below, enamel above. Dentinal tubules passing into von Ebner's enamel spindles. Branching of tubules also shown. High power. (Courtesy of Dr. John B. Stein.)

porous specimens of enamel immersed in the saliva of the immune individuals showing high calcium content. He then immersed teeth in a solution of saliva to which was added acid calcium phosphate and tricalcium phosphate and obtained less penetration by silver nitrate on these teeth, showing partial calcification.

R. W. Bunting and U. G. Rickert.—Find that the enamel is not complete when first formed, but hardens with age, and that the tooth is a permeable membrane. They succeeded in passing calcium salts through both enamel and dentin by osmosis and claim that when the calcium salt concentration in saliva is high, there is increased permeation of calcium into enamel. Furthermore, that owing to changes or fluctuations in composition of blood and saliva there is an increased deposit of calcium salts from the circulation of the pulp into the tooth substance as well as a similar deposition from the saliva inward.

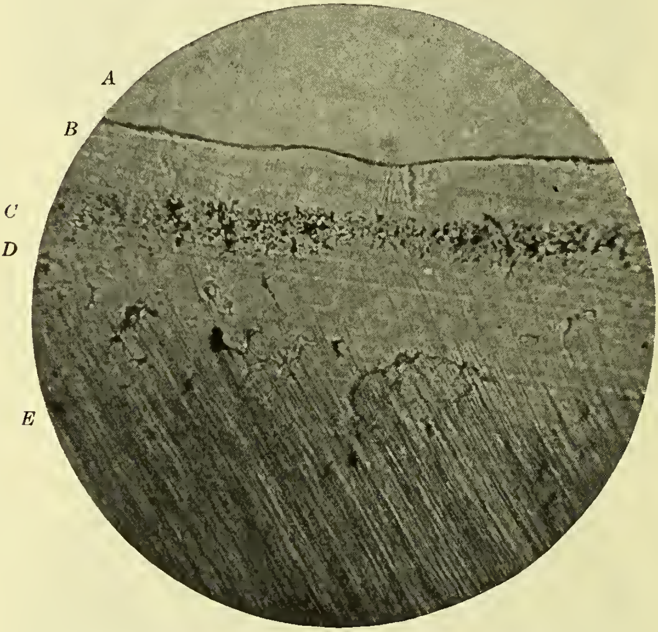


Fig. 151.—Cementum and dentin, low power. A, cementum. B, dento-cemental junction. C, granular layer. D, inter-globular spaces. E, dentinal tubules. (Courtesy of Dr. John B. Stein.)

Weston A. Price.—Finds that calcium ions may be readily dialized through the enamel and an increase in weight of the specimen may be noted following this phenomenon.

Percy Howe.— Has demonstrated that albumin, globulin, and other colloids pass from the blood through the salivary glands into the saliva, that both blood and saliva contain carbonates and phosphates greatly in excess of their solubility in water and that CO_2 is an important factor in maintaining these substances in solution in fluids undergoing calcification.

Charles F. Bödecker.—Has corroborated the findings as to permeability of the hard tissues of the tooth.

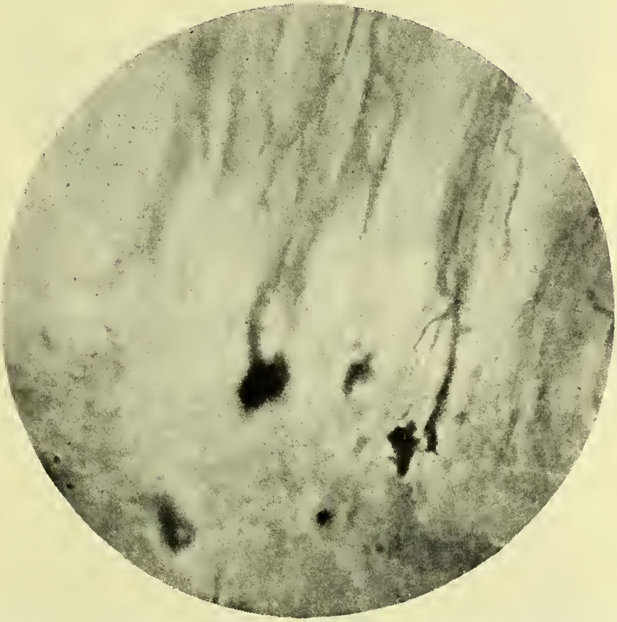


FIG. 152.—Dentino-cemental junction. Dentinal tubules above in communication with cemental lacunae below. (Courtesy of Dr. Lester R. Cahn and the Publisher of Dental Items of Interest.)

The opposing claims of various authorities with reference to the histologic and nutritional relationships between the dentin and cementum are also very confusing and as yet unsettled. Differences reported in findings with reference to the structure of enamel and the other hard tissues of the teeth are mainly due to the difficulty of obtaining thin stainable sections and to confusing of interpretation, owing to refractive phenomena in ground sections. Charles Tomes, C. F. W. Bödecker, Howard Mummery, Harold K. Box and Lester R. Cahn all claim the presence of a dentino-cemental communication, while Frederick Noyes, G. V. Black, Hopewell-Smith and others deny its presence. Weston A.

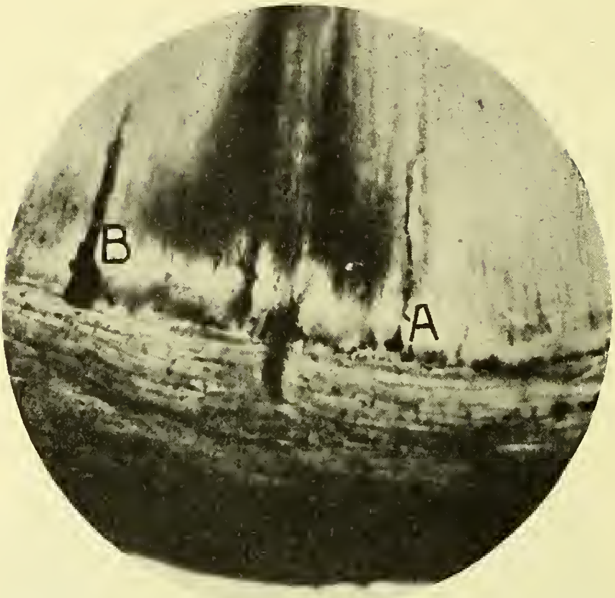


Fig. 153.—Dentino-cemental communication. Channels seen at A and B. (Courtesy of Dr. Lester R. Cahn and the Publisher of Dental Items of Interest.)

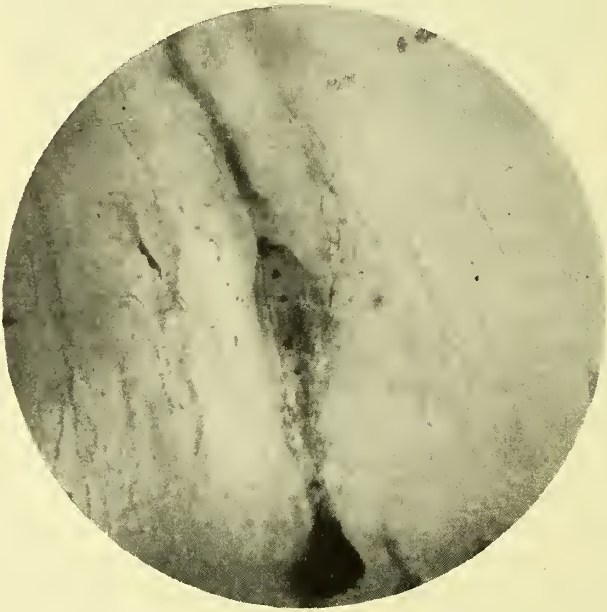


Fig. 154.—Dentino-cemental communication. Dentinal tubule in communication with a cemental lacuna. (Courtesy of Dr. Lester R. Cahn and the Publisher of Dental Items of Interest.

Price in his "Dental Infections," Vol. 1, pages 197–198 states that "In the formation of the tooth, both dentin and cementum are built upon a first zone of calcification which is in effect a continuous fire wall or protective zone between the two structures with but relatively few direct connections or openings from the dentin to the cementum . . . A large proportion of the total communication is limited to the foramina (apical and lateral) . . . The boundary between dentin and cementum is in effect a dialyzing membrane and that electrolytes may pass through that membrane quite freely while colloids cannot."

The author believes that ultimately it will be definitely determined that all of the hard tissues of the tooth are subject to some form of nutritional, metabolic or osmotic change, these changes occurring intradentally from the general circulation and also from without intraorally via the salivary fluids. These determinations have a direct and important bearing on our knowledge of caries production and prevention, periodontal disturbances in relation to pulp disease, as well as on the importance of preservation of the pulp, root canal therapeutics, and root filling technic. At the end of this chapter is appended a reference bibliography for use of those wishing to pursue the subject further.

Charles F. Bödecker claims that through his celloidin decalcifying method he has demonstrated the possibility of the passage of lymph from the vessels of the pulp through the dentinal tubules to the enamel lamellae and thence throughout the enamel via the enamel root sheaths, which latter he claims, are delicate organic envelopes surrounding the enamel rods throughout their entire length. William J. Gies in making a chemical analysis of the soft sponge-like remains of the organic enamel matrix obtained by Doctor Bödecker made the following report in the Journal of Dental Research, Vol. VI, pages 145–147.

"Since no insoluble material except a protein mass gives the biuret test under the severely exclusive conditions in this experiment, the result, repeatedly obtained, presents conclusive chemical evidence of the protein in enamel, and of the occurrence there of true protoplasmic ('organic') matter, in accord with Bödecker's prior deductions to the effect on histological grounds.

"The foregoing proof that the matrix contains albuminous matter did not include a determination of the nature of the contained protein. It might be keratin, the chief protein constituent of all other extodermal structures in the higher animals, but this is merely a reasonable guess. An attempt will be made to ascertain the quality and relationships of the protein. Pending such a determination, any discussion of the organic matrix as a factor in the nutrition of the enamel must remain speculative.

"The following facts, among many, have a significant bearing on a solution of the problem of nutrition in enamel.

"1. The smaller the structure in which nutrition or metabolism occurs in a mammalian tissue, the larger the proportion of the selective cellular nuclei involved; but no cellular nuclei have yet been found in the enamel matrix.

"2. It has not been shown that the organic matrix itself is not densely mineralized in the enamel.

"3. Movement of water in the enamel (as in a lamp wick) might occur wholly by capillarity or osmosis and without any selective character.

"4. Movement of substances (in solution) by capillarity or osmosis may be beneficial, indifferent, or destructive, without being nutritional.

"5. Nutrition is a process of selective acquisition in the structure that is being nourished. It involves a tripartite procedure—assumption, transformation, and rejection of materials—resulting in renewal of mass and in removal of waste. It is not a one-way traffic but a process of come and go.

"6. The enamel protein is stained deeply by trypan blue. Some years ago the present writer demonstrated in dogs that while enamel is being produced trypan blue after its injection into the circulation is absorbed into the enamel and is permanently retained; but that after enamel has been formed, trypan blue does not pass into it from the circulation, although the pigment enters the dentin. Since injected trypan blue is removed from all stained parts of the living body except dental enamel (after its passage into enamel under the special conditions just stated), it is probable that the degree of true nutritional transformation as distinguished from simple mechanical change in enamel after its production is very slight if not wholly negative.

"7. If the enamel matrix is entirely inert chemically and devoid of nutritive influences, it is possible nevertheless that physical (mechanical) transmission of ions and molecules on or in its framework, distinct from physiological (selective) movement but inaugurated or controlled by conditions external to the matrix, might account for important effects on the enamel. Changes of this character appear to be the kind that Doctor Bödecker has projected but which he terms nutritional.

"Doctor Bödecker's very significant findings may lead to important discoveries, especially as to the origin and the prevention of dental caries. Such developments will be accelerated rather than retarded by searching scrutiny of all hypotheses regarding the function and dynamic relationships of the organic matrix."

The researches conducted or still in progress in this field are too numerous to mention in a work of this nature. Although some progress has been made, many phases of the subject are still in dispute. Therefore, it is impossible to reach definite conclusions in regard to these matters at this writing However, keratin has been definitely found in enamel.

NUTRITION AND DIET

From a study of the preceding section, it is now apparent that until the relation of nutritional processes on fully formed enamel can be more definitely determined, the possibility of controlling during life the integrity of this tissue through dietary and other means is conjectural. If the enamel is subject to change in its structure through dialysis of calcium salts from the saliva or through the passage of life-giving forces from the pulp, the importance of these measures is self evident. However, it may readily be seen that prenatal and early post-natal influences are at least important in the laying down of healthy, well developed enamel structures, consequently, the diet and health of the pregnant and nursing mother have a definite bearing on the formation of bones and teeth of her offspring. Also, since it is conceded that dentin, cementum, bone and all soft tissues of the body are subject to nutritional influences, the importance of prenatal care and maintenance of the highest type of metabolic integrity of the individual after birth cannot be over estimated in its bearing on the development of dentin, cementum and the periodontal structures, in order that they may be best enabled to resist disease processes. It will also be admitted that in the infant and the young, nutritional influences will certainly affect the enamel as well as the other parts of the developing permanent teeth.

Important researches in this field by Pickerill, Price, Howe, Wallace, Mellanby, Grieves and many others, together with those mentioned in the preceding section on the embryologic and histologic structure of the teeth again reveal the determination and ability of the dental profession to solve her individual problems. This outstanding work is the most significant in character promulgated since that done in the field of focal infections and is of equal if not greater importance in its bearing on the prolongation of human life through oral and dental preventive measures.

Dietary Considerations.—An analysis of the dental literature shows that hundreds of articles dealing with effect of dietary variations upon the structure of the teeth and bones appeared during the period of time from 1912 to the present writing. The names of E. V. McCollum, J. H. Kellog, W. J. Gies, P. R. Howe, M. Mellanby, J. A. Marshall, C. J. Grieves, Sim Wallace, J. Leon Williams, M. T. Hanke, H. F. Hawkins. A. Höjer, A. Hrdlica and John B. Stein may be mentioned among the prominent writers in this field, and the reader is referred to their work. A review of most of these writings has convinced the author that it is impossible at this time to offer very definite conclusions. However, since all can agree that proper attention to diet is recognized as an important general health measure and since we believe that it has definite prenatal and early post-natal influence on the development of bone and tooth structure, it is important that the dentist have at least a general knowledge of the subject in order that he may apply this knowledge to the demands of his own and his pateints' welfare.

All animals are a type of heat engine, the food consumed being the fuel, while the heat radiated from the body is the output. Animal bodies also utilize the nutritive substances necessary for the maintenance of life as they are found in other animals or in plants. The food from these sources supplies to the body the elements for promoting growth, repair of tissues, energy for muscular activity and heat, and for regulating body processes. Before they can be utilized they must first be digested and broken up into simpler compounds, many of which are discarded and others assimilated and built up into the proteins, carbohydrates, fats and mineral elements, which constitute the important parts of the animal body. With human beings the first important consideration here is adequate and thorough mastication and insalivation of the food masses in order that they may be carried into the stomach in a proper condition for the digestive juices to be brought into contact with them. Since the saliva contains ptyalin, the nonproteolytic ferment, it might be said that mastication and insalivation are the first of the digestive processes.

All authorities lay stress on the necessity for a well balanced diet of proteins, carbohydrates, fats and substances supplying an inorganic content, viz.: mineral salts, particularly phosphorous and calcium. The proteins (meat, fish, fowl, eggs, cheese, peas, beans, and nuts) furnish the pabulum for building up of the tissues and for the repair of waste. The carbohydrates (vegetables, except vegetable protein, cereals, rice, flour, fruits, sugar and confections) and the fats (meat fats, vegetable fats, cream, butter and nuts) supply the energy, while the substances contributing to the inorganic needs (chiefly calcium and phosphorus and iron) of the body are vegetables, fruits, greens, and bran in whole wheat.

Milk contains some of all these four classes of foods and may be considered a balanced diet. The amount of each of these classes to furnish a balanced diet will vary with the age, climate, mode of living, and temperament of the individual, a balanced diet for one person being frequently unsuitable for another.

The Vitamins.—It has been demonstrated in many experiments that animals may be fed a well balanced ration, according to the above schedule, grow to maturity in a normal way and yet soon begin to decline and arrive at the age of senility if certain elements are omitted from the dietary. It is important then that these elements which I shall presently mention be included in the regular diet of man, if normal metabolism is to be maintained and if prolongation of life and the productive period be desired. In the experiments of McCollum, Howe, Mellanby and others,

VITAMIN CHART

Classification	Properties	Contained in
Vitamin A Anti-Ophthalmic Anti-Infective	Fat Soluble. Lost when exposed to air. Inactivated when exposed to Ozone. Builds resistance.	Cod Liver Oil, Orange, Grapefruit, Pineapple, Butter, Eggs, Milk, Carrots, Maize, Cabbage.
Vitamin B (B^1) Anti-Neuritic	Soluble in water, alcohol and acidified alcohol. It is dialyzable. It is destroyed at 130°C. Prevents or cures Beri-beri.	Orange, Grapefruit, Pineapple, Lean Meats, Milk, Yeast, Wheat, Beans, Peas, Lentils.
Vitamin C Anti-Scorbutic	Alcohol soluble. Destroyed by Ozone. Destroyed by heat. Prevents or cures Scurvy.	Orange, Tomato, Lemon, Oyster, Apples, Bananas.
Vitamin D Anti-Rachitic Sunshine vitamin	Soluble in oil and alcohol. Calcium depositing substance.	Cod Liver Oil, Milk, Egg yolk.
Vitamin E Reproductive Anti-Sterility	Fertility conferring factor. Cannot be identified with A, B, C or D.	Lettuce, Meat, Rolled Oats, Whole Wheat, Milk, Fats.
Vitamin G (B^2) Anti-Pellagra	Water soluble. Stable to cooking temperatures. Prevents degenerative nerve changes.	Yeast, Eggs, Liver, Lean Meat, Spinach, Green Beans, Wheat Germ.

The Anti-Ophthalmic Vitamin A and the Anti-Rachitic Vitamin D are the Vitamins of Cod Liver Oil. Investigators have found that it would take four kilograms of spinach or carrots to furnish as much Vitamin D as is contained in one teaspoonful of Cod Liver Oil.

it was found that by omitting these same elements and yet feeding the animals on a diet of proteins, carbohydrates, fats and inorganic materials, these animals soon developed swollen joints, rickets, pyorrhea, loss of eyesight and other disturbances. It may then readily be perceived that diet is an important consideration to the dentist. In both instances the particular factors omitted were what are termed for lack of a better name accessory food substances or vitamins. At present, we really know very little about these accessory food substances, except that four important types have been discovered in addition to a number of others. The chemical isolation of some of the vitamins has been reported. The early isolation of others is a probability. One type occurs in butter (butter fat), in cod-liver oil, to a smaller degree in meat fat and other foods but is not found in vegetable fat. It has been given the name soluble fat A, or vitamin A. A second type of these substances, Vitamin B, (or B^1), which is water soluble, is found largely in the green leaves of plants, such as celery tops, lettuce, cabbage, chard, turnip tops, spinach, brussel sprouts, etc. The third type, Vitamin C, is found in fruit juices, principally orange juice and in tomatoes, is antiscorbutic in character and favors bone formation. Another type, Vitamin D, is found principally in cod-liver oil and is anti-rachitic in action. Vitamin E, supposedly stimulates the reproductive powers and is found in lettuce, rolled oats, whole wheat, milk, etc. Vitamin G (or B^2) is known as the pellagra preventing vitamin and is found in yeast, eggs, liver, lean meat, wheat germ, spinach, green beans, etc. Vitamin F has also been announced, but discontinued, as it was found to be linoleic acid.

The table on page 121 gives the chief sources of the supply of the vitamins.

The average diet in the United States consists largely of white bread, from which a large amount of nutriment, including vitamins, has been removed by the milling process; meat in too large quantities for the average individual to assimilate; potatoes; and sugar in some form. This diet does not nearly approach even the balanced ration previously mentioned and contains very little of the accessory food factors or of the mineral elements necessary for the building up of good bone and tooth structure. In addition, the large quantities of sugar usually included directly stimulate the production of caries and produce an overload on the liver and other digestive organs, thus resulting in increased mucin deposition in the saliva and acceleration of the formation of the bacterial plaque.

As far as the dentist is concerned a faulty diet leads to faulty tooth and bone formation, defective metabolic processes, with resultant tendencies toward periodontoclasia, as well as caries production. Inquiry into the dietary habits should then be a routine procedure in diagnosing oral disturbances, and faults in this direction should early be brought to the attention of the patient.

The ideal diet is one in which a sufficient amount of dairy products (milk, butter, etc.), leafy vegetables (lettuce, spinach, brussel sprouts, celery tops, beet tops, cabbage) and fruits are included with the idea of largely reducing the amount of white bread, muscle cuts of meats and sugar and supplying the necessary vitamins and mineral elements. There should also be included plenty of substances of a fibrous nature to stimulate the functions of mastication and peristalsis, as well as an abundance of water.

Distribution of the Vitamins

Vitamin A protects tissue of head, thorax, sex glands, etc.; Vitamin B is anti-neuritic and growth-promoting; Vitamin C protects tissues of the mouth; favors bone formation; Vitamin D is growth-promoting and antirachitic; Vitamin E promotes the reproductive powers; Vitamin G (B_2) is nutritive to the nerve tissues and prevents pellagra.

	A	B	C	D	E	G (B_2)
Apples, fresh	**	**	*	—	—	*
Asparagus, cooked	***	***	—	—	*	*
Bananas	**	**	**	—	*	*
Beans, green, string, raw	***	**	**	—	*	**
Beef, fat	*	—	—	—	*	—
Beef, lean	—	*	*—	—	*	**
Beets	*	*	*	—	—	*
Bread, whole wheat, milk	***	***	—	—	*	*
Butter	****	—	—	*	*	—
Cabbage, green, raw	***	**	***	—	**	*
Cantaloupe	*	*	*	—	—	*
Carrots, raw	****	**	**	—	—	*
Cauliflower	**	*	*	—	—	*
Celery	*	***	*	—	*	*
Cheese	***	*	—	—	—	*
Cream	***	*	*	—	*	
Eggs, whole	***	**	—	**	*	**
Egg, yolk	****	***	—	***	**	*
Eggplant	*	*	—	—	—	*
Flour, whole wheat	*	***	—	—	*	*
Grapefruit	*	**	**	—	—	*
Grapes	*	**	*	—	—	*
Kale	*	***	**	—	**	*
Lemon juice		**	****	—	—	
Lettuce	***	**	***	—	****	*
Liver	****	***	*	*	*—	***
Milk, whole, cow's	**	**	*	**	*	*
Milk, dried, whole		***	*	**	*	
Oatmeal	**	**	—	—	—	*
Onions, raw	*	**	**	—	*	*
Orange juice	***	**	****	—	*	
Oysters	***	*	—	—	—	*
Parsnips	**	**	—	—	—	*
Peaches	***	**	*	—		
Peanuts	*	**	—	—	*	*
Peas	***	**	—	—	—	*
Pineapple	**	**	**	—	—	*
Potatoes, white	**	*—	*	—	—	*
Potatoes, sweet	***	*	*	—	—	*
Prunes, fresh		***	*	—	—	*
Pumpkin	***	*	*	—	—	*
Salmon	*	*	—	*—	—	**
Spinach	****	***	*	*—	**	***
Swiss chard	*	**	*	—	**	**
Tomatoes, raw or canned	***	***	***	—		*
Tomato juice	**	***	****	—		*
Turnips, yellow	**	**	*	—	—	**
Wheat, germ	**	****	—	—	****	***
Yeast, dried, brewery	—	****	—	—	—	****
Watercress	****	***	***	*—	**	*

* Present, but generally in insufficient quantities.
** Fair.
*** Good.
**** Excellent source.
— Traces or absent.

Full discussions of the vitamins are found in modern texts on Nutrition and on Physiological Chemistry. Sufficient has been said to recall that the vitamins are substances of unknown chemical composition, found in the cells of animals and plants, which are necessary to maintain the health of the tissues of the body; and that since they apparently cannot be synthesized by the organism, they must be furnished preformed, together with the fats, proteins, carbohydrates and mineral salts, the long recognized nutrient materials.

Under ordinary conditions a properly selected diet should afford the necessary vitamins as well as the other constituents of a well-balanced ration. When deficiency diseases of mild character manifest themselves the condition can often be corrected by recommending the proper foods to supply the desirable vitamins. In the graver cases and under special circumstances cod liver oil, halibut liver oil, viosterol and other medicinal preparations may be resorted to.

Calcium Fixation.—Calcium is normally present in practically all cells and tissues of the body. The great bulk of it is combined as phosphate and carbonate to form the inorganic structure of the teeth and bones. The remainder, about one per cent is present in the remaining tissues. The normal functioning of muscular, nervous and glandular tissues depends among other factors on their concentration. In health the calcium of the blood plasma contains ten milligrams per one hundred cubic centimeters. If this proportion drops to seven milligrams per one hundred centimeters, tetany may result. The blood corpuscles contain very little calcium.

The minimal daily calcium income for normal adults is about 0.5 Gm. per day. Double this amount, 1 Gm. daily, is indicated as a safe margin (Sherman). Calcium deposition in the body depends on adequate supply of calcium and vitamin D. This is thought to be related to the function of the parathyroid gland. The normal daily diet should supply sufficient calcium for the body needs. When diets deficient in calcium are used, deficiency of calcium often results. This in ordinary cases may be prevented or overcome by a regular intake of foods rich in calcium, such as milk, green vegetables, whole wheat, eggs, etc. In addition, vitamins A, C, and D are claimed to be necessary for proper calcification of teeth. However, dietary experiments and the use of the vitamins are at present in an experimental stage and much additional research is necessary before the application of this knowledge can be scientifically applied in dental therapeutics.

Boyd and Drain and other investigators claim that caries may be arrested by diets of high mineral content and vitamin A, C, and D. Although caries and pyorrhea alveolaris are claimed by recent writers to be largely due to defective calcium metabolism, no definite scientific proofs have been advanced in substantiation of these statements. More satisfactory evidence is necessary before the researches of these investigators can be fully accepted.

Parathyroid deficiency in infants is claimed to be responsible for delayed formation and eruption of teeth and for the production of orthodontic irregularities and malocclusion. The apparent close relationship between deficient calcium diets, parathyroid deficiency and deficient vitamin intake to abnormal development of teeth and bone and the incidence of diseases of these structures becomes of increasing interest and suggests that closer relationships should be established between the dentist and the physician in attempts to prevent and treat these conditions from a nutritional standpoint. However, more definite information is necessary before further advances can be made in these fields without the possibility of great harm being done. Diets advised for the treatment of disorders of the teeth and supporting structures may possibly exert an undesirable influence on other parts of the body. Therefore dentists must realize that these structures are merely a part of a very complicated organism.

The administration of special preparations of calcium salts, in addition to enforcement of strict dietary regulation is being advocated in such conditions, as tetany, rickets, osteomalacia, caries and periclasia. The entire problem is at present in an experimental stage and therapy of this nature should be very carefully watched if attempted and inaugurated only after very careful study. It has been found that administration of calcium salts by mouth in the treatment of tetany has been of temporary benefit only, unless the cause has been sought and remedied. Otherwise the disease returns after discontinuance of the calcium administration.

Use of parathyroid extract sometimes produces temporary increase in blood calcium even in the absence of calcium administration. Deficiency of blood calcium is not always the cause of osteomalacia and rickets, since it has been found in these diseases that in some cases a defective deposition of calcium in the bones occurs, regardless of the presence of adequate calcium blood content. The same may be possible with the teeth. In these cases sources of vitamin D must be supplied. Where calcium deficiency is actually present, the condition may possibly be benefitted by proper calcium diets, the administration of calcium salts and vitamin D.

THE ENDOCRINE GLANDS

At the present time there is considerable evidence that the glands of internal secretion (the endocrines) excercise an important influence over the metabolic activities of the body. They are believed to exercise two very important functions, viz. *first:* control of the development and differentiation of tissues during growth of the body, and *second:* regulation of the generation and mobilization of energy, together with the establishment of the normal rate of basal metabolism.

All of these glands have a coordinate inter-relationship and disturbed function of one supposedly interferes with the action of others. *The thyroids*, through their hormone, determine the rate of energy production and control the nutrition of the skin, the development of the skull and brain and the rate of basal metabolism. *The adrenals* are composed of two parts, viz. the cortex and the medulla. The cortex influences brain development, normal growth of the body and sexual development, while the medulla assists in the materialization of body energy for emergencies and in the maintenance of the tone of the blood vessels. The adrenals are also supposedly concerned in the exhibition of fear, anger and other psychic manifestations. The *para-thyroids* are concerned in the assimilation and fixation of calcium, and lowered functions of these glands interfere with the development of teeth and bone. In the light of our present findings an adequate supply of vitamin A and D is necessary for their proper functioning. *The pituitary gland*, among other functions, regulates the concentration of sodium and probably potassium in the blood.

Thus it may be seen that the glands of internal secretion are greatly concerned in the maintenance of normal nutrition of the body and have a very definite influence on dietary considerations, since even though a well balanced ration for the individual be observed, if these glands do not function properly the result expected cannot be obtained. Inadequate fixation of lime salts, poor bone and tooth development may be due to lack of lime in the dietary, lowered functioning of the para-thyroids or lack of the necessary vitamins and activators to stimulate lime fixation.

Doctor Weston A. Price[2] in his recent writings has reported interesting results of his studies of activation, utilization and metabolism of calcium. Much valuable information has been obtained by him through the use of a specially constructed spectrograph, but these experiments and others which he has conducted are as yet too incomplete to enable us to reach very definite conclusions. However, as a result of this work and that of Mellanby, Howe, Boyd and Drain, Hanke, Hawkins, McCollum and other investigators, it is believed that the internal administration of such substances as calcium gluconate, calcium lactate, activated cod-liver oil and viosterol may be of great benefit in stimulating faulty calcium metabolism concerned in the building of healthy bone and tooth tissues.

The scope of this work will not admit of further consideration of these subjects. The reader is referred to the references at the end of this chapter for further information.

Bibliography

1. Bödecker, Chas. F.: The practical significance of the organic matrix in enamel, Jour. Dental Research, vol. VI, no. 2, June 1924–26, p. 131.
2. Price, Weston A.: New fundamentals for treatment of dental diseases based on calcium utilization, etc., Jour. Amer. Dent. Assoc., March 1929, p. 456.

Hopewell-Smith, Arthur: Concerning human enamel; facts, explanation and application, Dental Cosmos, vol. LXVIII, July 1926, p. 639.

Bödecker, Chas. F.: Enamel lamellae, Jour. Amer. Dent. Assoc., Oct. 1928, p. 1885.

Van Kirk, Lawrence E.: Variations in structure of human enamel and dentin, Jour. Amer. Dent. Assoc., 1928, p. 1231.

Kato, Seiji: The histological study on human enamel, Shikwa Shimpo, vol. XXI, nos. 5, 6, 7, 8, 1928.

Leonard, Harold J.: The causes of variation in salivary calcium, Jour. Amer. Dent. Assoc., Aug. 1928.

Ruthrauff, W. M.: The organic structure of enamel rods, Brochure.

Ruthrauff, W. M.: Secretory tubes in human enamel, Brochure.

Ruthrauff, W. M.: Landmarks in dental research, Brochure.

Marshall, Jno. A.: Experimental findings in nutrition studies, Dental Cosmos, Nov. 1928.

Chase, Sam'l W.: The structure of the dental enamel, Jour. Amer. Dent. Assoc., May 1927, p. 868.

Leigh, R. W.: Studies of the enamel, Jour. Amer. Dent. Assoc., April 1927, p. 592.

Orban, Balint: Histology of the enamel lamellae and tufts, Jour. Amer. Dent. Assoc. Feb. 1928, p. 305.

Mummery, J. Howard: The structure of enamel and dentin, Jour. Amer. Dent. Assoc. Feb. 1927, p. 205.

Beust, Theodore: Intrafollicular enamel development, Jour. Amer. Dent. Assoc., Nov. 1928, p. 2021.

Bödecker, Chas. F.: A report of further investigation on human enamel, Jour. Dental Research, vol. VI, no. 2, June 1924–26, p. 117.

Bödecker, Chas. F.: The practical significance of the organic matrix in human enamel, Jour. Dental Research, vol. VI, no. 2, June 1924–26, p. 131.

Marshall, Jno. A.: Diet in relation to disease of the supporting tissues, Jour. Amer. Dent. Assoc., Dec. 1927, p. 2207.

Howe, Percy R.: Diet as related to prevention of mouth disease, Jour. Amer. Dent. Assoc. vol. X, no. 8, Aug. 1923, p. 755.

Howe, Percy R.: Some experimental effects of different diets, Dental Summary, March 1924, p. 212.

Box, Harold K.: Studies in periodontal pathology, Bulletin No. 7, Canadian Dental Research Foundation, May 1924.

McGehee, W. H. O.: Constitutional treatment of dental diseases, Dental Summary, April 1910.

Williams, J. Leon: Can we, by a change in food habits, change the structure of formed enamel? Dental Cosmos, LXIX, June 1927.

Clark, Guy W. and Shell, Jno. S.: Influence of diet upon inorganic constituents of human saliva, Dental Cosmos, May 1927.

Owre, Alfred: Diet as related to diseases of the mouth, Dental Cosmos, Sept. 1926.

McCollum, E. V.: Nutritional value of milk, etc., Report of 8th Internat. Dairy Congress, April 18, 1929.

Owre, Alfred: Diet and dentistry, Univ. of Minnesota Press, Nov. 1924.

Leonard, Harold J.: Preventive dentistry in public schools, Pacific Dental Gazette, Oct. 1924.

Karshan, Maxwell: Chemistry and staining reactions of keratin, Jour. Dental Research, April 1930, p. 181.

Price, Weston A.: Seasonal variations in butter-fat vitamins, etc., Jour. Amer. Dent. Assoc., May 1930, p. 850.

Gies, Wm. J. and Collaborators: Studies of dental caries, etc., Jour. Dental Research, April 1930, p. 215.

Boyd, J. D. and Drain, C. L.: Jour. Am. Med. Assoc., vol. 90, p. 1867, 1928.

Hanke, M. T.: Jour. Amer. Dent. Assoc., vol. 17, p. 957, 1930.

Hawkins, H. F.: Jour. Amer. Dent. Assoc., vol. 16, p. 781, 1930.

CHAPTER V

PREVENTION OF ORAL DISEASES (*Continued*)

PREVENTION OF DENTAL CARIES AND PERIODONTOCLASIA—CAUSES OF CARIES—CAUSES OF PERIODONTAL DISEASE

To the researches of W. D. Miller, G. V Black, Leon Williams and others nearly half a century ago are we indebted for most of our fundamental knowledge in regard to the local causes of dental caries. Miller in 1882 described many of the minor organisms which he claimed to be concerned in caries production. Through their action on fermentable carbohydrate food debris in the mouth and the resultant formation of organic acids, principally lactic, he determined that they were responsible for the disintegration of the inorganic constituents of the enamel and dentin, thus establishing the fact that the condition is infective in character. Leon Williams established the fact that the formation of a mucinous bacterial plaque on the surface of the tooth is concerned, since it is necessary to confine the germs and the fermentable material through this protective covering to a definite locality for the production of the condition. Under the mucoid plaque, which consists largely of deposited mucin from the saliva, bacteria, epithelial cells and carbohydrate food debris, the process of acid production and enamel dissolution proceeds until an initial cavity is formed. Following this the bacteria penetrate deeper and deeper, involving the dentin, which later is broken down through a continuation of the fermentative process and a liquefaction of its organic constituents through the process of putrefaction. Although many additional phases of the carious process were worked out by other investigators, the classic researches of Miller and Williams stand as a monument to their name. At the time of his death, Miller was investigating methods for the prevention of caries through the action of the brush and the dentifrice.

The caries process may be divided into two characteristic phases, viz.,

First.—**Penetrative Fermentation,** viz., a dissolution of the inorganic salts of the enamel and dentin by lactic and other organic acids which result from fermentation of carbohydrates by the oral micro-organisms.

Second.—**Disintegrative Putrefaction,** viz., a destruction of the organic colloidal materials, the proteins, through the action of putrefactive bacteria. The changes incident to this putrefactive process are the same as those occurring in the putrefaction of all albuminous substances (which contain the elements C, H, O, and N, in their molecule) resulting in the ultimate formation of such end products as carbon dioxid (CO_2), ammonia (NH_3), hydrogen sulfid (H_2S), water (H_2O), acetic acid ($HC_2H_3O_2$) and other combinations of simple structure.

The enamel, owing to its small amount of colloidal constituents, is destroyed largely through fermentative processes, but, as will be readily understood, the putrefactive process is a large factor in the disintegration of dentin owing to the presence of a large amount of colloidal material in the tubules as well as in the matrix. The above agencies may be considered the exciting causes of caries. These exciting causes are controlled to a degree by the general predisposing causes already mentioned and through them by very important local predisposing causes. These latter may be conveniently grouped under the general heading of (1) defective structure of the enamel and dentin, (2) irregularities of the teeth and (3) vitiated or deficient oral secretions.

That such defects as faulty union of enamel in pits and fissures, cracks in or fractures of the enamel, hypoplasia of the enamel and dentin, and imperfect deposition into these tissues of calcium during the formative periods increase the susceptibility to the caries process is well understood. The influence of irregularities of the teeth, abnormal interproximal spaces and imperfectly constructed contact points is also well recognized. We are at present concerned with the question of the influence of the fluids in which the teeth are bathed, the local environment, as etiologic factors.

Extension for Prevention.—The chief contribution of G. V. Black to the question was the introduction of his operation known as "Extension for Prevention," fully discussed in the chapters on Preparation of Cavities. Dr. Black determined that caries was largely confined to the proximal surfaces of the teeth and to pits and fissures of occlusal, buccal and lingual surfaces, while other areas, particularly the axial line angles, were relatively immune. It then became a self evident fact that cavity margins extended to these relatively immune areas were less susceptible to decay, the operation then becoming a preventive measure.

Influence of Civilization.—Carl Röse and others claim that dental caries is largely due to inheritance and to physical degeneration as a result of civilization, Mendel's law and panmixia. Primitive man bad better teeth and was less subject to caries. He chose a mate who was physically sound with strong teeth necessary for the mastication of the coarse foods on which they subsisted. The children resulting from a union of this primitive type inherited a strong physique with sound teeth and continued through succeeding generations with relative immunity to caries. Civilization, however, has produced a lower type of physical manhood and womanhood, and the changed food habits requiring less mastication have resulted in a poorer type of denture much more subject to caries. Röse, therefore, considers caries as a problem in eugenics and advocates the intermarriage of only those who are physically fit and with sound dentures. He claims that caries is not in itself a disease but a symptom of general physical degeneration, the gauge to human health. He also claims as a result of the examination of a large number of school children in Germany that the drinking of water high in calcium content and the eating of foods containing high calcium content produces well formed hard teeth while opposite conditions are produced from opposite causes. For this reason, he advocates a high calcium diet and an abundance of natural mineral water with high calcium content for the building of hard resistant teeth.

Nutrition and Diet.—The work of Sim Wallace, H. P. Pickerill, William J. Gies, Russell W. Bunting, William Ruthrauff, Zilva and Wells, Percy Howe, McCollum, Grieves, the Mellanbys and others has previously been mentioned. All of these investigators have made signal contributions to our as yet meagre knowledge of the influence of diet and nutrition on caries production. As a result of their findings many have concluded that the key to the prevention of dental caries will be found not in the application of local, but in the application of dietary measures. The production of caries in the teeth of many lower animals through the feeding of scorbutic diets or diets deficient in calcium balance and vitamin content is undoubtedly of significant importance. The findings of explorers in the Arctic region, the South Sea Islands and in other parts of the globe also evidence the strong probability of the influence of diet in this connection. Uncivilized races inhabiting these regions and possessing teeth notably free from dental caries have been found to rapidly succumb on changing their mode of living, adopting civilized habits and living on the diet of civilized man. These findings have recently been confirmed by Dr. L. M. Waugh in a bulletin published by the United States Public Health Service entitled "Report of the Studies of the Teeth of the Esquimos of North Bering Sea and Arctic Alaska." An abstract of this report appears in the Journal of the International Association for

Dental Research, June 1930. Other writings of Dr. Waugh on this subject have subsequently appeared in the literature. Price and others have also reported more recent findings confirming these facts.

Edward C. Kirk has emphasized the fact that excessive consumption of certain carbohydrates may lead to faulty metabolism of these products in the liver and the production of an excess of fermentable glycogen in the saliva, with consequent increased susceptibility to caries. Numerous writers have brought out the fact that excessive sugar consumption results in an increased production of mucin in the oral secretions, thus facilitating the localization of food masses and the formation of bacterial plaques. These facts should be borne in mind in the selection of a proper dietary.

External and Internal Factors.—It is a self-evident fact that caries must be due to causes arising either outside or within the teeth, or both. The available evidence at our disposal strongly points to the conclusion that it is due in most instances to a combination of both internal and external factors. The *external* factors relate in quite a degree to the local environment of the teeth themselves and the fluids in which they are bathed, but the state of the secretions of the oral cavity in which these organs are bathed is largely regulated by *systemic conditions.* The *internal* factors concern more especially those relating to and affecting the nutrition and structure of the enamel and dentin and the character of the oral fluids, including diet, influence of the endocrines, intestinal stasis and general health measures.

A phase of the subject of diet in its bearing on caries production on which too little stress has been laid is that of its influence on the general condition of the lower bowel. A preponderance of protein foods frequently has a tendency to lead to intestinal stasis and constipation with resultant toxemia and lowered bodily vigor; whereas there is a lessened tendency in this direction with the carbohydrate foods. This has an important bearing on the susceptibility of the individual to caries of the teeth, not only through its effect on the general health of the patient, thus leading to lowered resistance of the teeth, but through its influence on the condition of the saliva itself.

Kellog[1] states that "It is important for the conservation of the teeth to keep the colon clean and free from masses of stagnating and putrefying food remnants. The colon is a most efficient incubator and when the dominant flora is proteolytic in character, stasis will necessarily give rise to the production of such enormous quantities of putrefactive products that the poison-destroying ability of the liver, kidneys, thyroid, suprarenal capsules and other structures is overtaxed and the tissues are flooded with such quantities of toxic material that the alexins and enzymes of the blood which normally afford ample protection through inhibiting the growth of bacteria become inoperative. The salivary and mucous secretions of the mouth become deteriorated, deficient in germ-destroying and inhibiting elements so the fluids with which the teeth are bathed do not protect them but rather furnish favorable nutrient media for the development of destructive organisms which are thus permitted to form in colonies on the gums or the teeth and carry on other destructive work. It is quite as important that the patient should be taught how to make his bowels move efficiently as to instruct him in the use of the tooth brush and other mouth-cleansing measures."

An essential consideration in connection with the question of diet is the importance of including sufficient lime-containing foods, together with the neccessary vitamins in the dietary. The organism requires a large daily supply of calcium in order that the metabolic processes of the body may be carried on properly. Deficient lime consumption as a result of lack of it in certain carbohydrates and proteins results not only in deficient tooth and bone formation but in a softening of these tissues after they are fully formed, since metabolic processes are taking place here at all times. Bungé, of Basel, and Sherman, of Columbia University, both agree that half of the civilized world is suffering from lime starvation. Since the body loses in the excreta about 13½ grains of lime daily, it is evident that this must be replaced through the consumption of lime-containing articles of diet or through dietary supplements.

There is very little organic matter in the enamel and we have to admit that this tissue cannot possibly be as subject to constructive and destructive changes as the dentin. At the same time, there is some organic material present there and even this tissue is, it is now believed by many, capable of some form of vital, chemical, or physical resistance to attacking pathologic agencies.

Nutrition in Enamel and Dentin.—The establishment of the fact that the enamel and dentin are subject to nutritional processes and to constructive and retrogressive changes has an intimate relationship to caries production as will readily be seen through a recognition of the establishment of internal resistance to disease processes.

It is believed by many investigators that vital teeth are capable of offering a certain amount of resistance throughout their periods of usefulness, to the inroads of pathologic processes. The following evidence has been offered in support of this belief, viz.

1. The pulp is the formative organ of the dentin and after tooth formation is complete it remains to furnish nourishment via the dentinal tubules to this structure. The dentinal fibrils are bathed in a serous exudate of living protoplasm which is exuded from the trophic pulp. On the life of the pulp depends the existence and welfare of the teeth (Figs. 156 and 157).

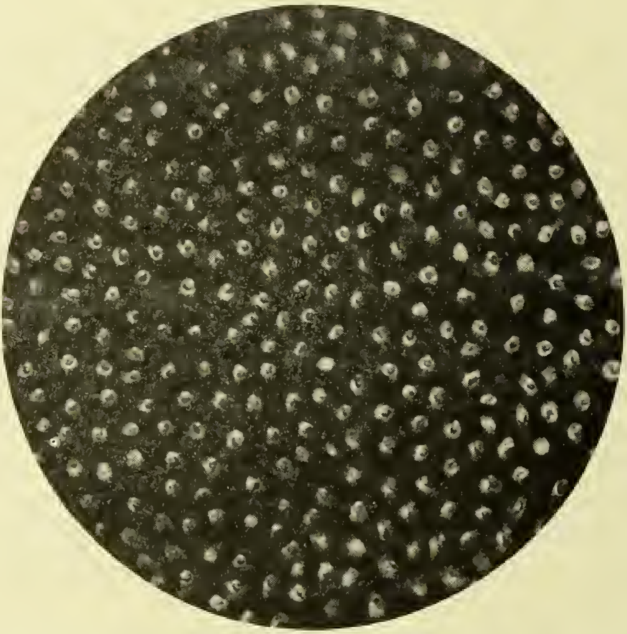


Fig. 155.—Transverse section of dentinal tubules, showing Tomes' fibres in the center surrounded by white lymph. Newman's sheath not shown. High power. (Courtesy of Dr. John B. Stein.)

2. The dentinal fibrils in some instances extend into the enamel. This is considered by some as an abnormality, but the condition is found frequently enough to be taken into consideration. Also, recent findings previously mentioned, indicate the presence of some form of nutritive influence via the enamel tufts and lamellae (Fig. 157).

3. When the tooth is subjected to abnormal influences such as caries, abrasion, erosin and other similar conditions, the pulp is irritated, responds to the impulse and interposes a wall of resistance against the attacking agencies in the form of a transparent zone, tubular calcification or secondary dentin. Hypersensitive dentin is also the result of vital action (Fig. 158).

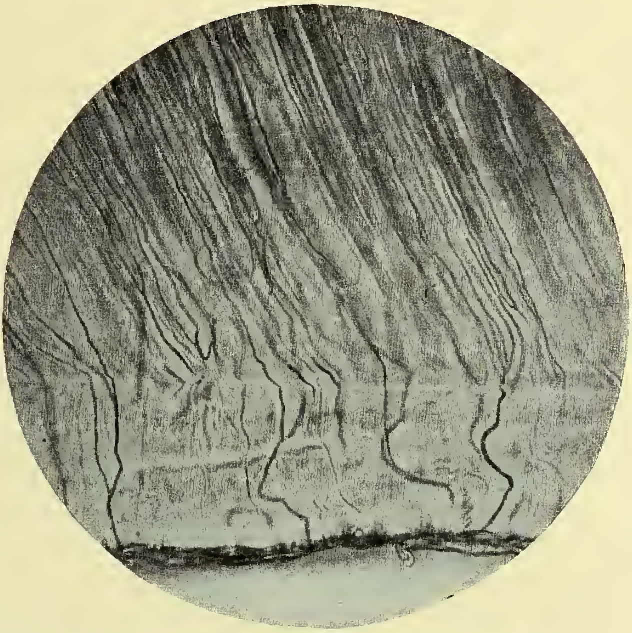


FIG. 156.—Dentinal tubules passing upward from the pulp chamber below. Low power. (Courtesy of Dr. John B. Stein.)

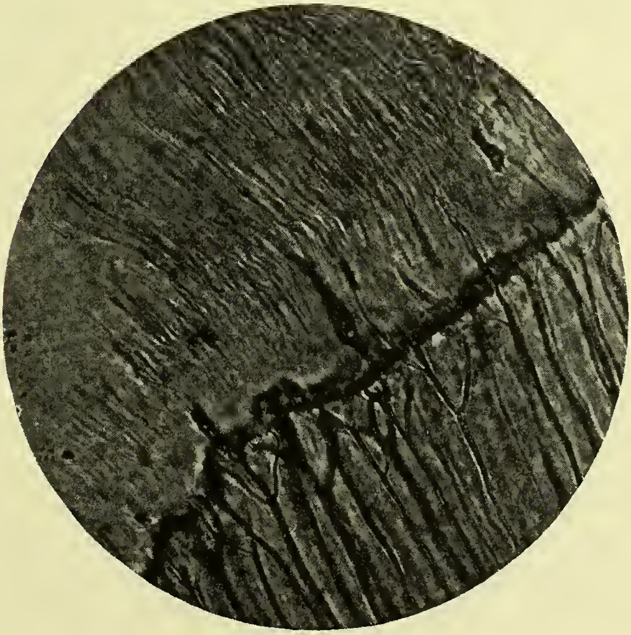


FIG. 157.—Dento-enamel junction. Enamel above, dentin below. Branching of tubules seen at their termination, with some passing into enamel spindles, seen in lower segments of enamel. (Courtesy of Dr. John B. Stein.)

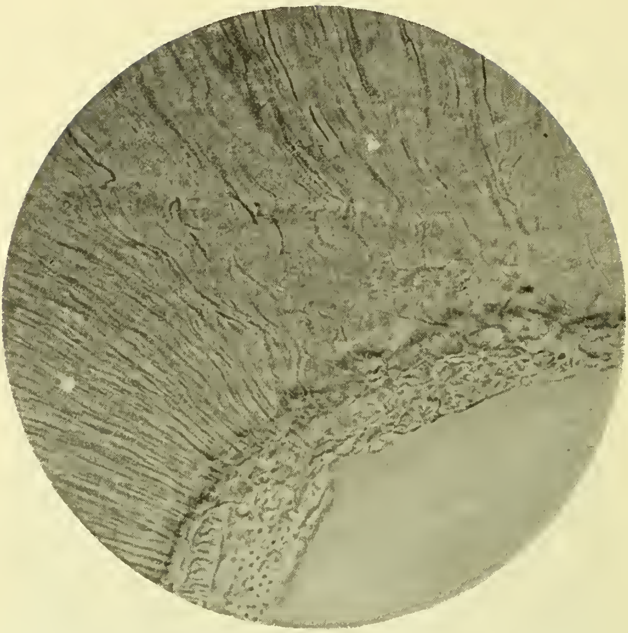


FIG. 158.—Dentin above, showing tubules in longitudinal section. Pulp chamber below. Adventitious dentin lining wall of pulp chamber, showing tubules in transverse section in lower left quadrant. (Courtesy of Dr. John B. Stein.)

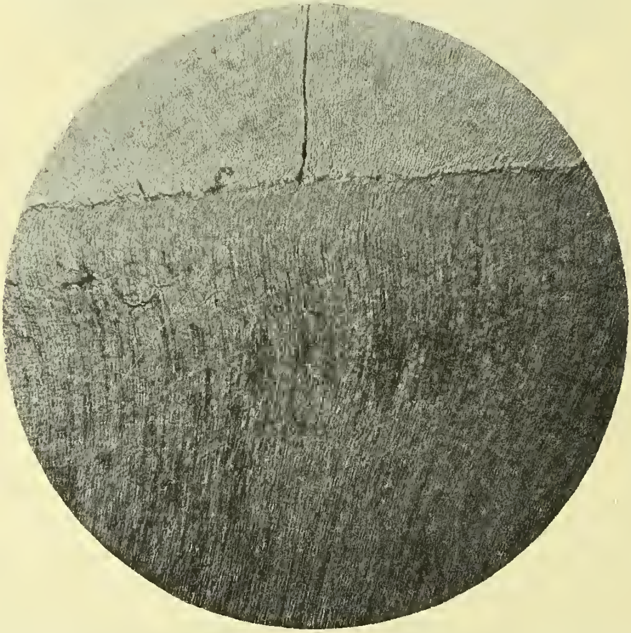


FIG. 159.—Dento-enamel junction in crown of tooth. Crack in the enamel above, dentin below. Note the inter-globular spaces beneath the junction. Low power. (Courtesy of Dr. John B. Stein.)

4. These phenomena are never found in pulpless teeth.

5. Clinical evidence demonstrates that de-vital teeth decay more rapidly. The dentin loses its strength, elasticity and translucency.

6. When the pulp of a tooth is removed for any cause, the enamel is much more subject to cracks, fractures, splitting off from the surface of the dentin, and rapidly progressing caries (Fig. 159).

7. The enamel, dentin, and cementum are capable of staining, either from within or without, by staining reagents, and the rapidity of staining is much greater in dead than in living teeth. The enamel is slightly receptive to staining agents when vital, but much more so when non-vital.

8. Causch, Buest, Bödecker, Heitzman, Klein, Tomes, Abbott, Von Ebner, Andreson, Morgenstern and others demonstrated the presence of living protoplasm in various forms in the enamel indicating that this substance is propably not completely out of the pale of nutrition.

9. Woods, Causch, Miller, Kirk, Gaskill, Hopewell-Smith, Burchard and others have reported cases of resorption of the enamel and dentin from within via the pulp, which could occur only through vital action. In some of these cases the resorbed areas have later been filled in by new depositions via the pulp.

10. In pregnancy, rickets, osteo-malachia and similar conditions, the bones and teeth are subject to retograde metamorphosis and absorption of their contained lime salts via the blood streams. The teeth are markedly more subject to caries in these conditions.

11. In sickness, convalescence, lowered vitality from any cause, the teeth are more subject to decay regardless of the regular hygienic care which may be given them. The condition is due in many instances, especially in rickets, osteo-malachia, gout, and diabetes, to the fact that not only is the resistance of the vital protoplasmic contents of the teeth lowered but also that in these conditions there is supposedly an excess of ammonium chloride formed in the blood which, reaching the vessels of the pulp, produces a dissolution or softening of the hard tissues of the teeth.

12. Black, to the contrary, Pickerill and others have demonstrated a change in the amount of calcium salts in the enamel with age, as well as a marked difference in the total amount in all of the tooth tissues in the so-called hard and soft teeth. This must necessarily be due largely to vital, physical, chemical or other functions or activities.

Comparative Anatomy.—Additional evidences of the soundness of these contentions are claimed through a study of the teeth of the lower animals. Tomes[1] classifies various varieties of dentin found in the teeth of man and the lower animals into (*a*) hard or unvascular dentin, (*b*) plicadentin (folds or waves), (*c*) vaso-dentin (vascular) and (*d*) osteo-dentin (resembling bone). He claims that vaso-dentin in which the canals are filled with capillaries from the pulp is natural to some mammalians such as the manitee, tapir, (Indian and American) and the megatherium, now extinct. It is common in fish such as the flounder, most flat fish (pleur onectidae) as well as in the ostracian and hake. According to Dewey and Thompson, in some instances, only the points of the teeth of the fish are covered with enamel. These authorities are also responsible for the statement that in the sloth (a mammal) the central axis is vascular dentin, while the outside investment is of harder dentin. Hopewell-Smith in his "Histology of the Teeth" page 17 makes the statement that in the artiodactyla, the enamel occupies a position between the dentin and cementum. The same author in his "Dental Anatomy and Physiology," page 301 says that the enamel of marsupials is tubular and that the condition is an example of atavism. He also states that vascular dentin is common to the hake (merlucius) and osteo-dentin to the esox-lucius. Tomes, in speaking of the enamel of some animals, states that the penetration of dentinal tubules into this tissue is characteristic of marsupials with the exception of the wambat; that the same condition exists in some rodents (the Jerboa) as well as in some insectivera (saricida); that they are characteristic in the enamel of the kangaroo and of the sheepshead fish. Burchard also calls attention to the fact that Causch's tubes are found in the enamel of many of the lower species, especially certain fish, and that either vasodentin or osteo-dentin is normally present in many, such as the hake, cod, sargus, flounder and haddock.

These instances have been cited by advocates of the so-called Vital Theory to emphasize the point that nature has in a large majority of cases made provision for the proper nutrition and continued vitality of most of the products of her handiwork, certainly as far as the lower order of beings is concerned and that it is irrational to suppose that some such provision has not been made to take care of all the tissues of her most perfect piece of mechanism, man. If this be true, then the teeth must certainly be capable of some form of vital resistance, since all living tissue possesses this property to a greater or less degree.

Chemical Considerations.—Others, arguing the question from a chemical standpoint have reached similar conclusions. When the pulp is removed from a vital tooth a change of matter occurs in the tooth. In change of matter (organic or inorganic) there is always a change in chemical composition. In a non-vital tooth, there is a continual chemical change taking place. The germs present in the mouth act more readily on the dead organic matter in the tooth than they will on living matter, while the acids of fermentation will act the more or less rapidly and forcibly on the inorganic constituents of the tooth, depending on the frequency with which the latter are changing their molecular relationships.

It is now recognized that the formation of a cavity of decay is due to a double decomposition, the acids of fermentation producing a dissolution of the inorganic constituents, while the ferments produced by certain micro-organisms digest the organic matter through the process of putrefaction.

Whenever organic matter undergoes decomposition, the process is generally accomplished by oxidation which causes a change in color. The organic is naturally the only part of the tooth which would undergo putrefaction, thus oxidizing the other elements, which turn the color. In vital teeth only decayed areas and those parts immediately beneath them change color, whereas in non-vital teeth the entire structure changes color, proving still further that there is a change in chemical composition. Therefore, there being a decided change in matter and chemical composition in devitalized teeth and the agencies producing the dissolution acting more readily during the progrees of such changes, there is necessarily greater susceptibility to morbid processes, including caries, under these circumstances.

I have dwelt at length on this question of "vital" resistance because of its importance in the establishment of the wisdom of certain statements I now wish to make. It is self-evident that the routine local hygienic measures advocated by the dental profession for the prevention and relief of caries of the teeth are affording, in cases in which they are practiced conscientiously and regularly, some relief, but it must be acknowledged that they are really falling far short of the promise of any great amelioration of the effects of the condition on the great mass of the people. I do not wish to be understood as in any way minimizing the great work which has been accomplished in the past by specialists in prophylaxis—work which is still producing such marvelous results; it is worthy of the greatest praise. But I do wish to make the statement most emphatically that these measures must in the future be considered as only half way measures. Local treatment may be considered as practically a failure, certainly as far as the stimulation of any hope of its ever being able to eradicate dental caries from the race. Local measures are very valuable and must always be of great importance, but we must seek further means of relief and these can be found only in the adoption of measures which will strike at the root of the systemic factors concerned.

Micro-organisms Concerned in Caries.—In his "Micro-organisms of the Human Mouth" W. D. Miller found ten different forms of micro-organisms capable of producing lactic acid fermentation of sugar-containing solutions. He claimed that "any germs capable of producing acid fermentation of food may take part in the first stage (enamel dissolution) of caries and that all those possessing a peptonizing or digestive action on albuminous substances may take part in the second stage and that those possessing both properties may take part in both stages." Leon Williams later reported numerous streptococci, cocci, diplococci, leptothrix and thread-like forms, and bacilli as present in caries and suggested that the type of germ might have a bearing on the rapidity of progress in caries. Subsequently, Goadby described the bacillus dentalis, which he said was present in all cases. Later, Kligler and Gies described three types of bacillus, namely, bacillus clantrix, caladothrodis placoides and leptothrix bacillus, which they believed responsible. Then Howe and Hatch mentioned the bacillus acidophilus, bacillus bifidus and three other types which they designated as bacillus X, Y, and M. Subsequently, Rutergay, an American, Lazarus Barlow and MacIntosh and James, English investigators, reported that two or three or more varieties of bacillus acidophilus were largely concerned. Based on the work of these latter investigators, Russel W. Bunting and his co-workers have reported at different times in the past few years numerous experiments tending to prove that dental caries is, as far as its bacteriologic aspects are concerned, a specific infection due in its incipiency to bacillus acidophilus. They report after examination of over 3,000 mouths that the organism is present in every active case of caries and that they have been unable to find the germ in the mouth in cases in which caries is absent. In cases of rampart caries they also report that elimination of these organisms produces a cessation of caries. In filthy, unkempt mouths, with no caries, the germ has been found absent in every instance. Bunting concludes that there is some inhibitive force in the mouths of certain individuals which prevents growth of this organism and protects them from caries and that this inhibition is connected in some way with diet, nutrition and the structure of the teeth. He claims to have demonstrated that the feeding of a well balanced diet in which *sugar and white flour is largely excluded* largely eliminates the growth and propagation of bacillus acidophilus in the mouth.

In the Journal of Dental Research, Vol. 12, No. 5, October, 1932 appears the report of an extensive and important research, entitled "Studies of the Causes and Nature of Dental Caries." This research was conducted by J. J. Enright, H. E. Friesell and M. O. Trescher at the Mellon Institute and the School of Dentistry of the University of Pittsburg, and was financed by E. R. Squibb and Sons. As a result of this work the authors reached the conclusion that the lactobacilli associated with caries of the enamel are lactobacillus acidophilus, Y type.

Vaccine Therapy.—Following the work of Bunting and his associates, Victor Ross, Francis Krasnow and Jerome Samet from the Laboratory of Biological Chemistry of Columbia University report in the Journal of Dental Research, 1929, as the result of extensive experiments the possibility of controlling the incidence of dental caries through vaccine therapy in an attempt to nullify the action of bacillus acidophilus, through its destruction by this means.

So voluminous is the literature and so rapid are the advances being made in the field of prevention that it is difficult to record them. Before this work is published, probably further knowledge will be gained. Undoubtedly at the present writing it appears that we are at least on the border line of vast discoveries in the field of diet and nutrition, of oral therapeutics and vaccine therapy as sources from which may be obtained the means for largely reducing the ravages of dental decay in the human race.

In the light of our present knowledge it would seem that the following tabulation, which is an epitome of the thoughts presented in this section, is a fair presentation of our modern conception of the causes of and remedies for the prevention of dental caries.

TABLE SHOWING FACTORS CONCERNED IN TOOTH DECAY

A. **Local Factors.**

1. Fermentation of carbohydrates (lactobacillus acidophilus, Y type).
2. Formation of bacterial and mucinous plaques.
3. Accumulation, deposition and putrefaction of proteins, affording a nidus for the localization of fermentable material and harmful bacteria.
4. Increased deposition of mucin in the saliva from excess sugar in the diet, resulting in acceleration of plaque formation.
5. Excessive excretion of glycogen (fermentable) in the saliva as a result of faulty metabolism by the liver of carbohydrate foods, or of irritation of the pituitary body by reflex action from pathological dentition and similar causes.

6. Diminution in the amount of saliva, changes in calcium and phosphorus balance and other chemical and dialytic content changes in the saliva, the natural cleansing and protective agent of the teeth.

7. Irregularities of the teeth and contracted arches.

8. Abnormal interproximal spaces and improper contact points (natural or artificial); defective and improperly finished dental operations.

9. Defective tooth structure from faulty union of enamel plates, imperfect deposition of calcium during the formative periods, cracks in or fractures of the enamel, hypoplasia of the enamel and dentin and similar conditions.

10. Recession of the gums, exposing unprotected dentinal and cemental surfaces at the necks of the teeth.

11. Inadequate mastication and lack of coarse fibrous foods in the dietary.

12. Improper care of the mouth.

B. Systemic Factors.

1. Improper dietary: (*a*) excessive carbohydrate diet, accelerating glycogen formation, which finally reaches the saliva; (*b*) excessive consumption of sugars, stimulating the increased deposition of mucin; (*c*) improper nourishment of infants (bottle fed) and expectant mothers, resulting in improper metabolism of calcium and phosphorus with resulting poor tooth-and-bone formation; (*d*) calcium imbalance and lack of ultra-violet radiation and of proper vitamins in the formative and later periods of life; (*e*) insufficient water in the dietary.

2. The sedentary life, resulting in lowered bodily vigor, anaemia, leukaemia, digestive disturbances, malnutrition, faulty metabolism, acidosis, nervous exhaustion and similar disorders, with consequent lessening of the resistance of the entire body, including the teeth.

3. Lowered bodily vigor from any cause, including inheritance and disease processes of any character, resulting in the production of poor tooth development during the formative stages or of retrograde metamorphosis in the same organs during the later periods of life.

4. Affections of the ductless glands resulting in (1) increased deposition of glycogen in the blood and saliva, (2) interference with calcium and phosphorous metabolism in the tissues of the body including the teeth, (3) as well as other imperfectly understood pathological changes.

The above table is a partial summary of our present conception of the etiology of the condition. Most of the factors mentioned are now accepted, but some of them have been denied as unfounded by certain investigators. A careful survey of this table will reveal certain important considerations, viz.:

1. That the active exciting causes of caries are to quite a degree the result of the failure on the part of the patient to appreciate the importance of the regular application of the ordinary laws of hygiene to the oral cavity.

2. That many of the local factors are, however, not concerned with conditions of a purely local nature, per se, but are dependent on certain faults in the dietary and on systemic conditions.

3. That four of the remaining local factors, viz. irregularities of the teeth, abnormal interproximal spaces, defective dental operations and recession of the gums are largely preventable or remediable.

4. That the single remaining local factor, viz. defective tooth structure, is the only one mentioned which is not now directly under the control of the dentist.

If we admit that the above statements are true, then we will have to acknowledge that the odium attached to the continued prevalence of this condition rests on the shoulders of our own profession, because we are the individuals to whom the public and the State will eventually look for its eradication.

A glance at the Systemic Factors mentioned in the table will reveal the significant fact that the majority of these are also preventable if we, as a profession, can secure the further cooperation of the medical fraternity in the promulgation of an aggressive campaign directed toward impressing on our patients the importance of right living and its intimate bearing on this condition. With a deeper knowledge on the part of the medical profession of oral conditions and a more profound understanding on the part of the dentist of the intimate relationship between diseases of the tissues with which he has to deal and systemic disturbances, there will be brought about a unity of action and interest of the two professions whose beneficial results cannot be over-estimated.

The following schedule of procedures appear rational from a study of the previous considerations.

SCHEDULE OF PROCEDURES EXPEDIENT FOR RELIEF

1. Continued education of students in the schools and of the profession in general as to the importance of the subject and the means to accomplish the desired result.

2. Continued and systematic research in the unsolved phases of the etiology, pathology and prevention of caries.

3. Securing of greater cooperation on the part of the medical profession in the recognition of the bearing of systemic conditions as causative factors and in the administration of constitutional treatment.

4. Education of the public through a continuation and extension of the oral hygiene movement, the establishment of institutions similar to the Forsyth and Eastman Dental Infirmaries and the Gugenheim Foundation throughout the country, the further equipping of dental clinics in the schools and the greater development of *industrial dentistry* in general.

5. Adoption and application of the following local and systemic preventive routine as indicated, viz.:

A DAILY SCHEDULE

1. *General Hygienic Measures.*—Maintenance of good health and bodily vigor through regular exercise, abundance of sunshine, fresh air, baths and similar measures. Control of the functions of the endocrines through cooperation with the endocrinologist. Avoidance of intestinal stasis, toxemia and similar conditions.

2. *Diet.*—Daily and regular consumption of an abundance of water. Regulation of the protein and carbohydrate constituents of the dietary according to the needs of the individual. Daily intake of an abundance of lime-and-vitamin-containing foods. Inclusion of acid fruits, vegetables and whole wheat bread in the dietary. Augmentation of the diet, particularly in the young, when indicated, by the addition of such substances as fish-liver oils, viosterol, calcium gluconate, etc., to satisfy the vitamin, mineral and nutritional needs of the person.

3. Sufficient mastication of adequate quantities of coarse, dry foods for their local cleansing and tonic effect and to stimulate peristalsis.

4. *Toilet of the Mouth.*—Absolute and continuous cleanliness of the mouth through the systematic institution of an oral prophylactic regimen by means of the brush, floss silk and similar measures.

PREVENTION OF PERIODONTOCLASIA

Periodontoclasia (pyorrhea alveolaris) is an infectious process or disease which produces or tends to produce a breaking down or destruction of the tissues surrounding the teeth, viz. the gums, pericementum, and alveolar process, due to the action of infective bacteria on the periodontal tissues. However, these organisms do not produce their characteristic results on tissues with high resistive powers. It is first necessary that the natural cell resistance of these tissues be lowered by some local injury or disturbance of circulation or nutrition. The gingival tissues possess normally a high degree of resistance against infections, due to an adequate blood and nerve supply. In the prevention of peridental disturbances the chief resort is the institution of measures designed to maintain the gingival tissues in a high state of health and vital resistive power.

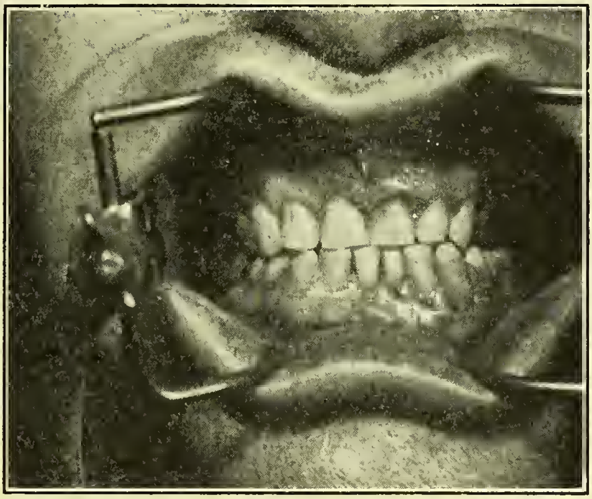


FIG. 160.—Recession and loss of regularity of gingival margin, with periodontal disease. (Courtesy of Dr. Sidney Sorrin.)

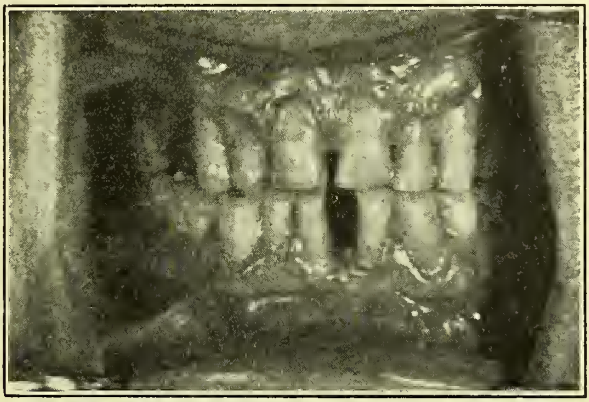


FIG. 161.—Periodontal destruction with profuse pus flow in patient with diabetes and syphilis.

If these measures be neglected and the gingivae are subjected to either local irritants or to some metabolic disturbance, inflammation (gingivitis) supervenes, the gingival crevice is opened and ideal conditions are established for the entrance and propagation of bacteria and the subsequent destruction of the periodontal tissues, with the development of periodontoclasia.

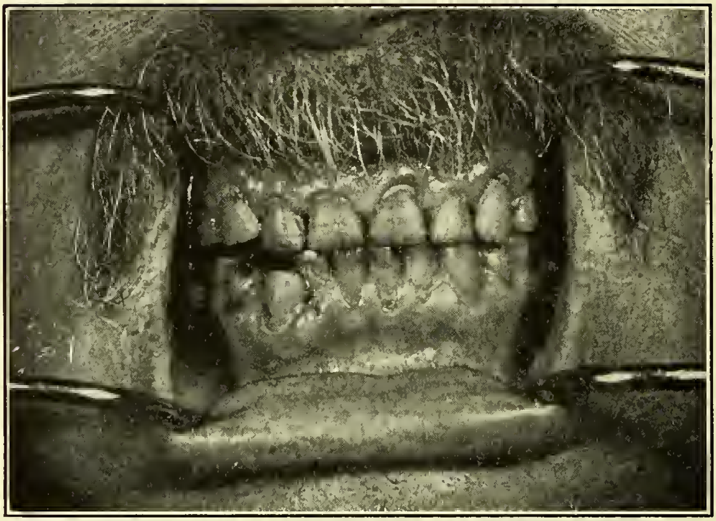


FIG. 162.—Non-occlusion due to pipe smoking. In this case the teeth were depressed to accommodate the pipe stem. Well marked periodontal disturbance and deposits. (Courtesy of Dr. Samuel C. Miller and The Journal of Dental Research.)

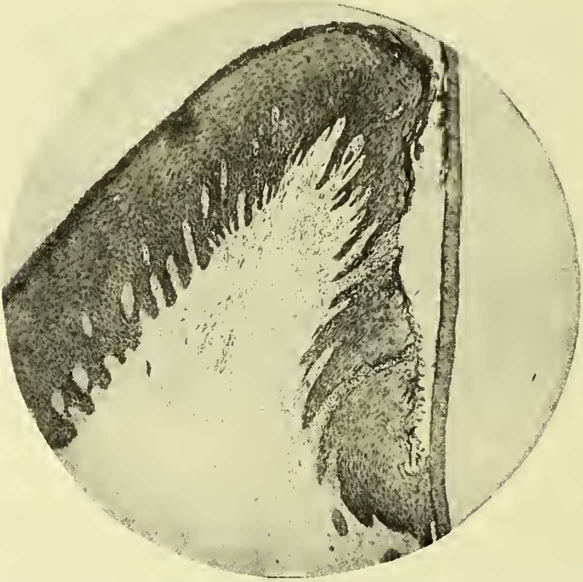


FIG. 163.—A break in the crevicular epithelium of the gingiva, exposing the underlying connective tissue to the fluids of the gingival crevice. (Courtesy of Dr. Harold K. Box.)

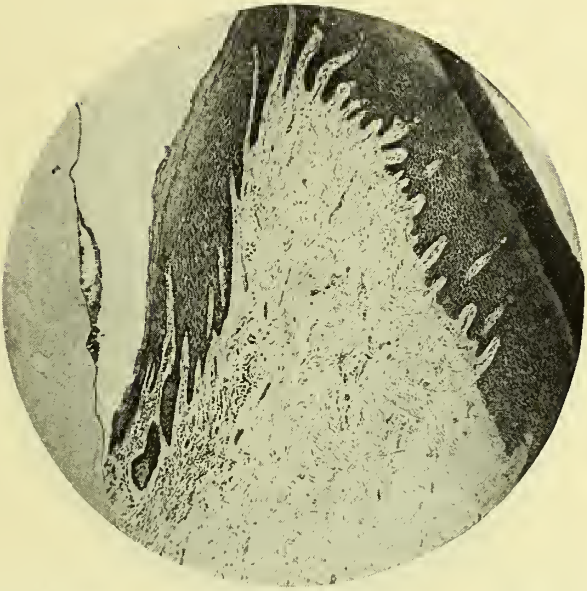


FIG. 164.—Gingival crevice and crest. Faulty junction of crevicular epithelium with tooth. (Courtesy of Dr. Harold K. Box.)

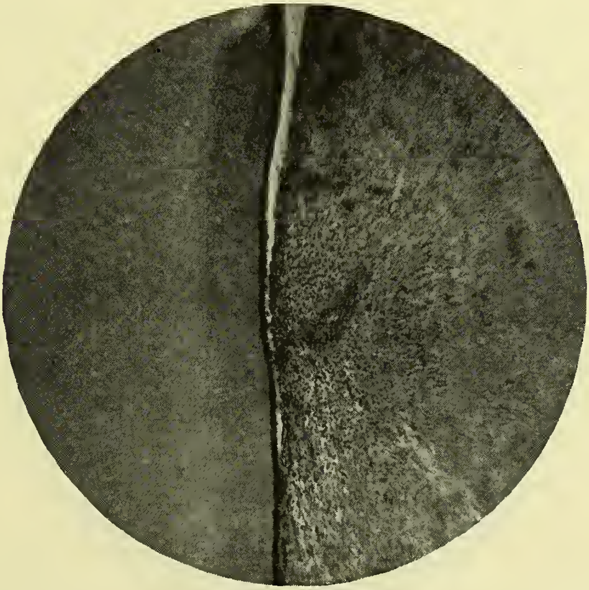


FIG. 165.—Early stage of pocket formation in the cemental gingiva. Soft tissue to the right covered with epithelium and affected with leucocytic infiltration. Dentin and cementum on the left. (Courtesy of Dr. Harold K. Box.)

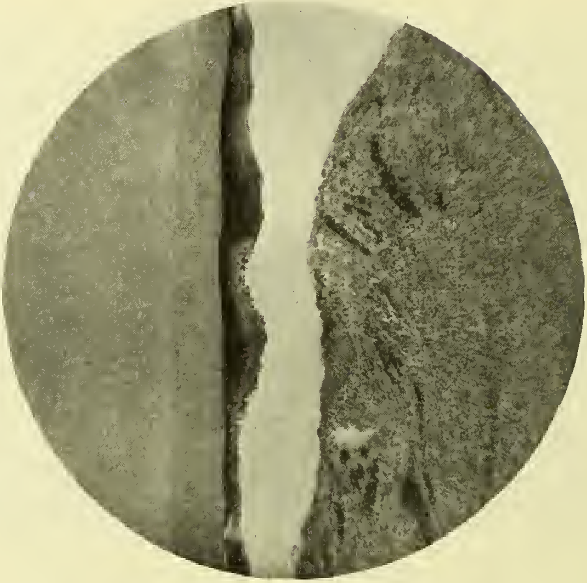


FIG 166.—Calculus on cemental surface in pocket. (Courtesy of Dr. Harold K. Box.)

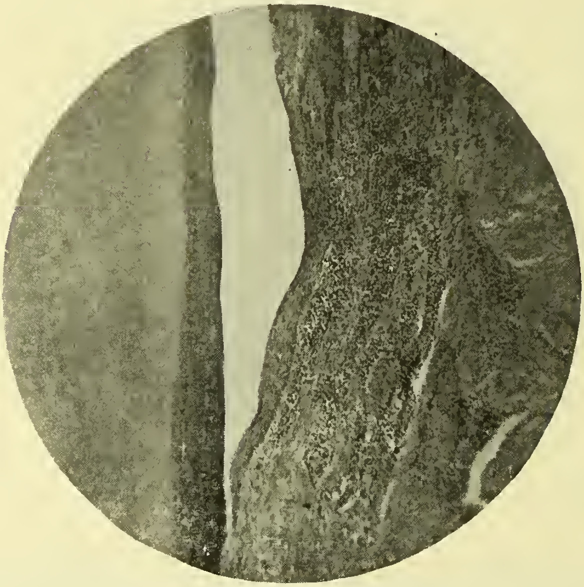


FIG. 167.—Fully formed cemental-gingival pocket. Dentin and cementum to the left, pocket in center, gingival tissues to the right, covered with epithelium and showing leucocytic infiltration. (Courtesy of Dr. Harold K. Box.)

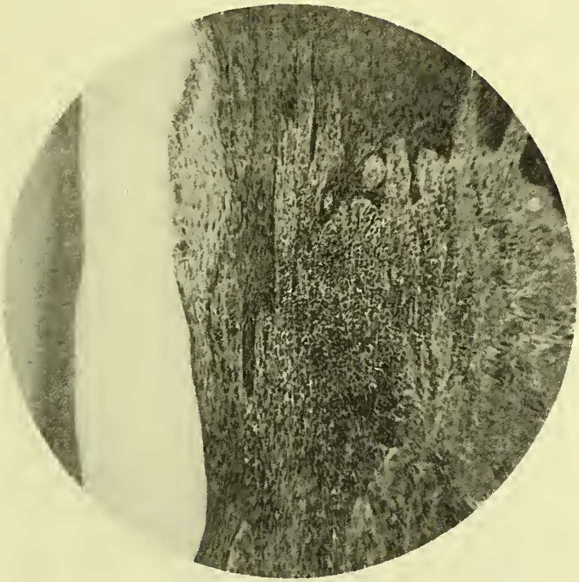


FIG. 168.—Chronic non-ulcerative gingivitis. Pronounced infiltration by lymphocytes and plasma cells. Epithelial covering above, cementum to the left and the gingival crevice between. (Courtesy of Dr. Harold K. Box.)

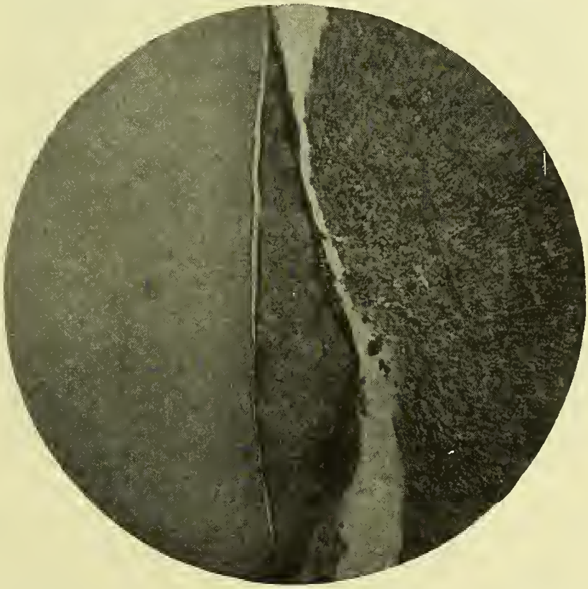


FIG. 169.—Calculus on cemental surface in pocket. Cementum and dentin to the left, calculus and pocket in center, and soft tissue to the right. (Courtesy of Dr. Harold K. Box.)

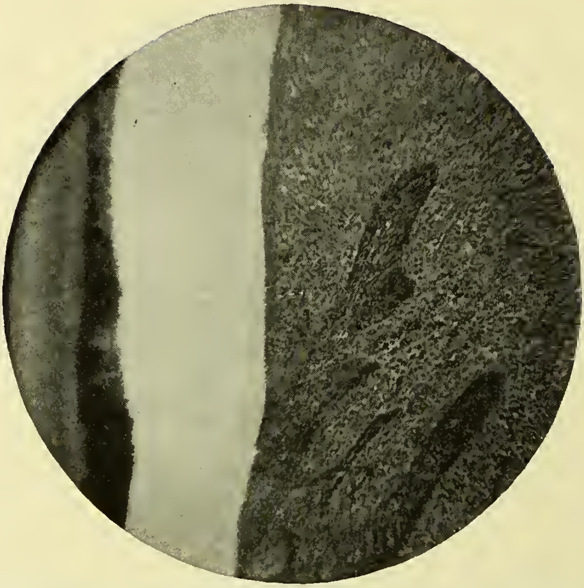


FIG. 170.—Pericemental pocket. Cementum covered by calculus on the left. Detached soft tissues on the right covered with epithelium and affected with leucocytic infiltration. (Courtesy of Dr. Harold K. Box.)

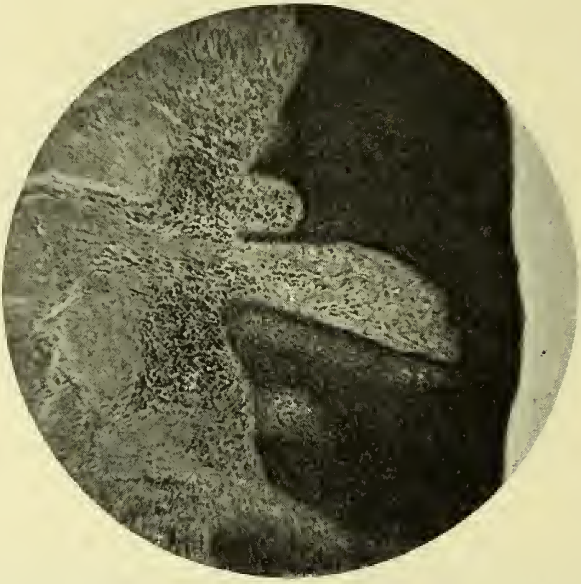


FIG. 171.—Chronic non-ulcerative cemental gingivitis. The tongue-like area in center is a connective tissue papilla extending into the epithelial layer. Above and below the base of this are areas of leucocytic infiltration. (Courtesy of Dr. Harold K. Box.)

Causes of Gingivitis.—The *local causes* of gingivitis are primarily traumatic injury from calculus deposits, impaction of food, overhanging cervical margins of fillings and crowns, improperly fitting bridges, traumatic occlusion of the teeth, chemical and bacterial irritants and similar conditions. The *systemic causes* are due to faults of metabolism, lowering the cell resistance of these parts. As a result of these two causes, infection and destruction of the tissue results.

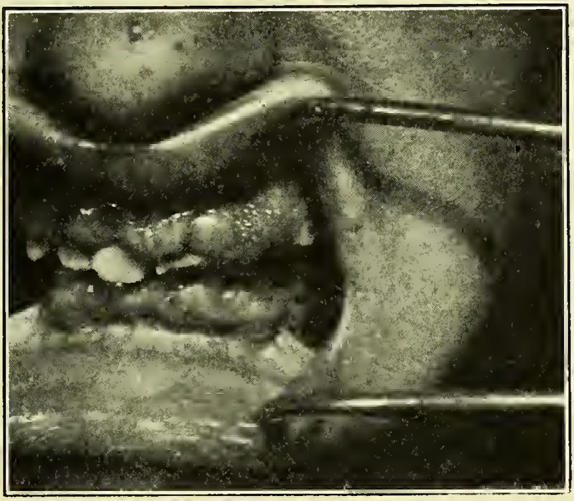


FIG. 172.—Proliferative gingivitis practically concealing the crowns of the teeth. (Courtesy of Dr. Sidney Sorrin.)

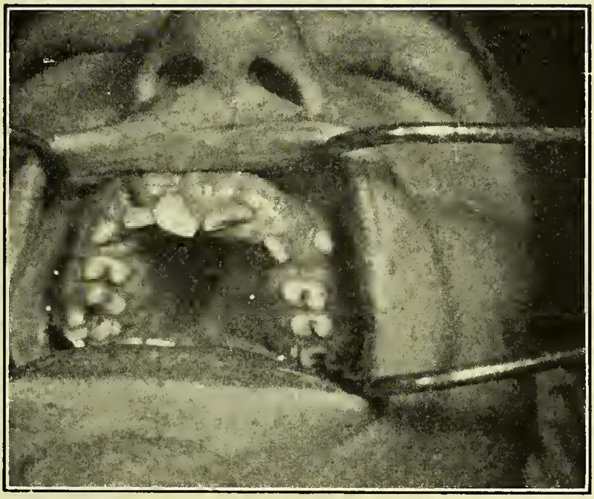


FIG. 173.—Proliferative gingivitis. (Courtesy of Dr. Sidney Sorrin.)

The prevention and control of gingivitis and other periodontal disturbances consists in the avoidance or removal of all local irritants, a raising of the tissue resistance of the parts through stimulation of the circulation and other prophylactic procedures, diet and general systemic measures.

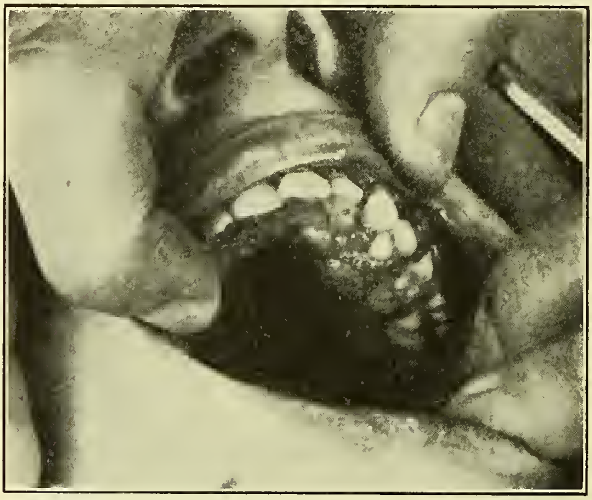


Fig. 174.—Gingivitis of pregnancy, a type of edematous gingivitis.

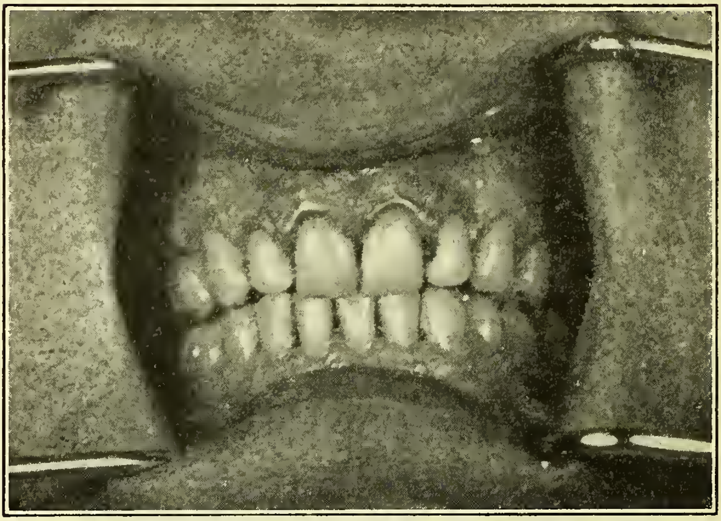


Fig. 175.—Pigmentation of alveolar mucosa in a light complexioned individual, following use of copper sulphate for the treatment of trachoma. Well marked gingivitis on upper anteriors.

It is without the scope of this work to enter deeply into the causes, pathology and treatment of periodontal disturbances, this lying more particularly in the field of periodontia. Suffice it to say that preventive dentistry and oral prophylactic measures are directed largely to the prevention of the two most important diseases of the oral cavity, viz. dental caries and periodontoclasia and that if these can be avoided many others of the ills of mankind for which they are directly responsible will be controlled.

Bibliography

1. Kellogg, John Harvey: Relation of diet to dental caries and mouth infection, The Dental Summary, 1915, vol. 35, pp. 656–847.
2. Tomes, Sir Charles S.: "Manual of Dental Anatomy," 8th ed., 1923, MacMillan Co.

Kellogg, John Harvey: The body's margin of safety, Pacific Dental Gazette, 1912, vol. 20, pp. 487–490.

Wallace, Sim: Prevention of common disease of childhood, Dental Record, 1912.

Wallace, Sim: Prevention of dental caries, Dental Record, 1912.

Pickerill, H. P.: "The Prevention of Caries and Oral Sepsis," 1912.

Bunting, R. W.: The tooth, a permeable membrane, Jour. Nat. Dent. Assoc., 1918, p. 519.

Dewey, Martin and Thompson, Alton Howard: "Comparative Anatomy," 2nd ed. rev. by Martin Dewey, 1915, Mosby.

McGehee, W. H. O.: Prevention dental caries, Dental Summary, vol. 38, no. 8, Aug. 1918, p. 597.

Hunter, Wm.: The new status and importance of dentistry, Dental Magazine and Oral Topics, Nov. 1929, p. 1169.

McGehee, W. H. O.: Prevention of dental caries, Dental Summary, vol. 36, no. 12, p. 1019.

McGehee, W. H. O.: Causes and prevention of dental caries, Dental Summary, vol. 37, no. 9, p. 635.

Bunting, R. W. and Parmerlee, Faith: Role of bacillus acidophilus in dental caries, Jour. Amer. Dent. Assoc., vol. 12, no. 4, p. 381.

Seccomb, Wallace: Dental caries in the light of present day knowledge of dental nutrition, Jour. Amer. Dent. Assoc., vol. XI, no. 4, p. 360.

Bunting, R. W.: Diet and its relation to dental caries, Jour. Amer. Dent. Assoc., vol. XI, no. 1, p. 647.

Hartzell, T. B. and Larsen, W. P.: Further studies of the etiology of dental caries, Jour. Amer. Dent. Assoc., July 1925, p. 784.

Rickert, U. G.: Rules for control and prevention of dental caries, Jour. Amer. Dent. Assoc., March 1923, vol. X, no. 3, p. 23.

Rickert, U. G.: Study of salivary and blood calcium in pregnancy, Jour. Amer. Dent. Assoc., vol. XI, no. 9, Sept. 1924, p. 783.

Howe, Percy R.: Experimental feeding with monkeys, Jour. Amer. Dent. Assoc., vol. XI, no. 12, Dec. 1924, p. 1194.

Cahn, Lester R.: Report on dentinal cemental communication, Items of Interest, July 1926.

Neustadt, Egon: Bone changes and their significance, Jour. Dental Research, vol. 14, no. 2, April 1929, p. 203.

MacMillan, Hugh W.: Structural characteristics of alveolar process, Internat. Jour. Orthodontia, Oral Surg. and Radiodontia, vol. XII, no. 8, Aug. 1926.

Hyatt, Thaddeus P.: A questionnaire on occlusal fissures and their treatment, Dental Cosmos, Nov. 1925.

Hyatt, Thaddeus P.: Prophylactic odontotomy, Dental Cosmos, Feb. 1924.

Hyatt, Thaddeus P.: Cavities, grooves, sulci and fissures, Dental Cosmos, Nov. 1923.

Hyatt, Thaddeus P.: Preventive dentistry, Dental Items of Interest, May and June, 1925.

Hyatt, Thaddeus P.: Industrial dentistry and the dental profession, Jour. Nat. Dent. Assoc., April 1921.

Gottlieb, Bernard: Traumatic occlusion, Jour. Amer. Dent. Assoc., July 1927, p. 1276.

Chase, Sam'l W.: Structure of dental enamel, Jour. Amer. Dent. Assoc., May 1927, p. 868.

Fish, E. W.: Circulation of lymph in dental enamel, Jour. Amer. Dent. Assoc., May 1927, p. 804.

CHAPTER VI

PREVENTION OF ORAL DISEASES (*Continued*)

ORAL PROPHYLAXIS (PROPHYLACTODONTIA)

The term prophylaxis is derived from the Greek words *pro,* before and *phylasso,* I guard, meaning literally the prevention of disease. Oral prophylaxis signifies the prevention of diseases of the oral cavity including the teeth and surrounding tissues. The term prophylactodontia is of the same origin and from the Greek *odous,* tooth. Both terms are synonymous with preventive dentistry, although oral prophylaxis applies more particularly to the local preventive measures now to be discussed, including:—

First.—Removal of deposits or concretions and stains from the teeth.

Second.—Polishing of all exposed portions of the teeth.

Third.—Removal of all overhanging portions of fillings, crowns and bridges and polishing them.

Fourth.—Restoration of all faulty contours and contact points.

Fifth.—Protection or filling of all defective pits and fissures (prophylactic odontotomy).

Sixth.—Prevention or relief of traumatic occlusion.

Seventh.—Stimulation of the soft tissues and removal of all evidences of septic infection.

Eighth.—Instruction of the patient as to the importance of regular personal oral cleanliness and health and in the means for accomplishing and maintaining it.

Ninth.—Insistence on regular periodic supervision on the part of the dentist.

Deposits in the Mouth.—The deposits and concretions occurring in the mouth are of various types and originate from different sources. They may be mentioned as follows, viz.:

First.—Salivary calculus depositing from the salivary glands on the crowns of the teeth and found in greatest amounts opposite the ducts of the parotid glands on the buccal surfaces of the upper molar teeth and of the sub-maxillary and sub-lingual glands on the lingual surfaces of the lower incisors.

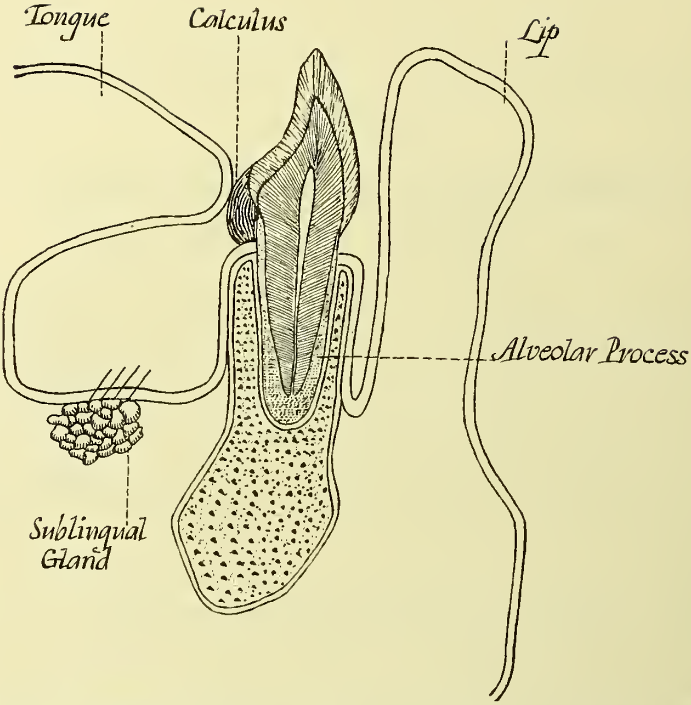


FIG. 176.—Deposit of salivary calculus on lower incisor. (D agrammatic.)

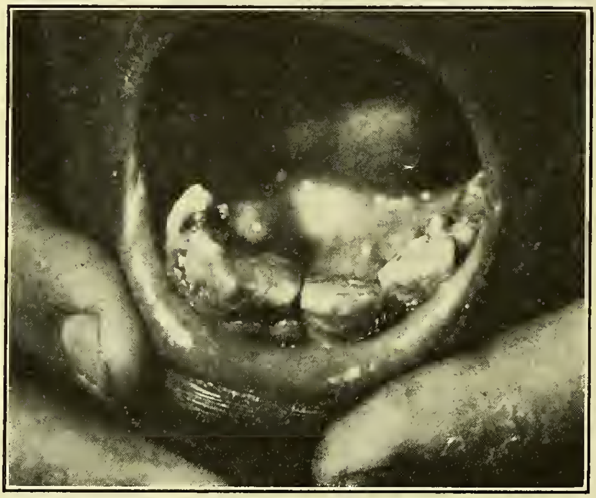


FIG. 177.—Excessive deposition of salivary calculus.

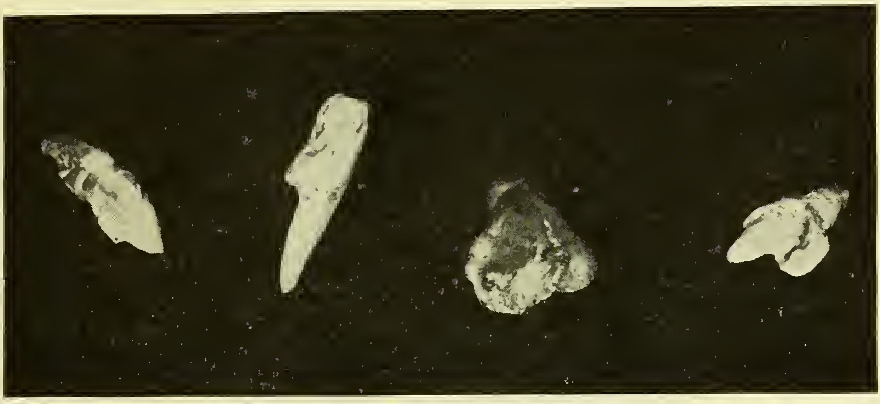


FIG. 178.—Teeth encrusted with calculus.

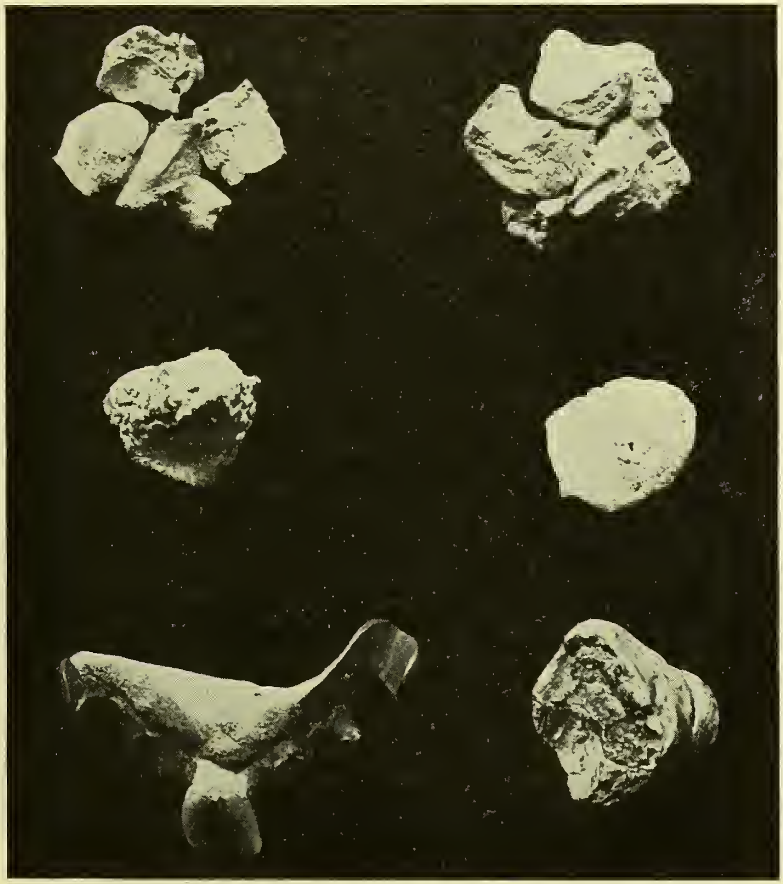


FIG. 179.—Salivary calculus. Lower left, partial denture encrusted with calculus.

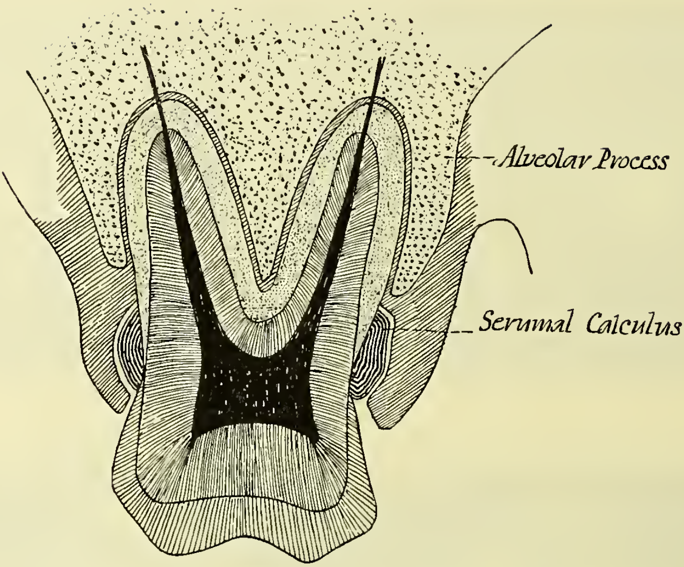


FIG. 180.—Deposits of serumal calculus on molar. (Diagrammatic.)

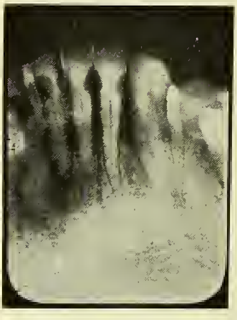


FIG. 181.—Marked alveolar absorption, caries and deposits of subgingival calculus.

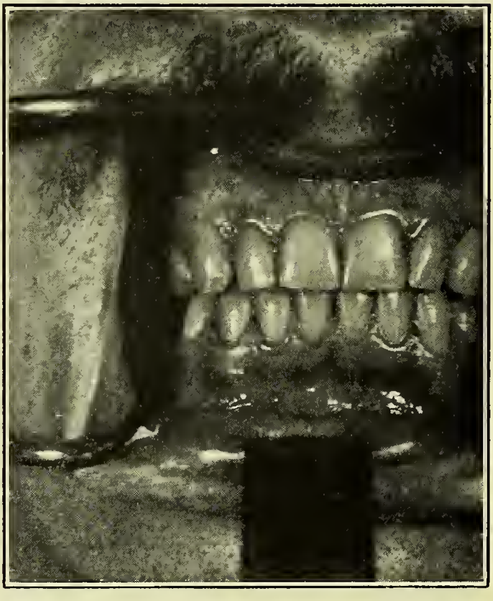


FIG. 182.—McCall's festoons seen over the upper lateral incisors. (Courtesy of Dr. Sidney Sorrin.)

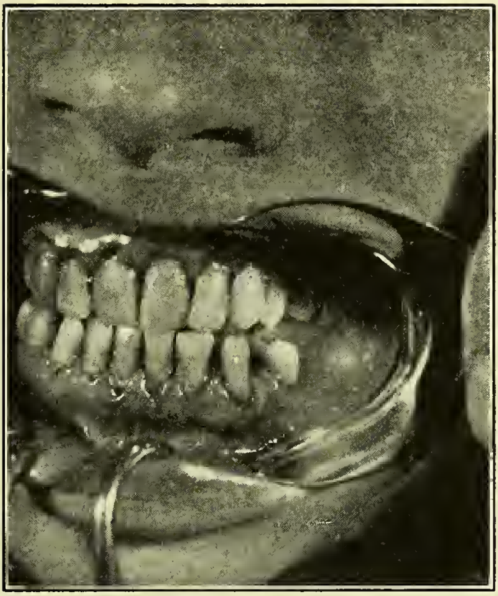


FIG. 183.—Moderately advanced case of periodontal disease showing irregularity of the gingival festooning. Stillman's clefts are seen on the two lower central incisors. (Courtesy of Dr. Sidney Sorrin.)

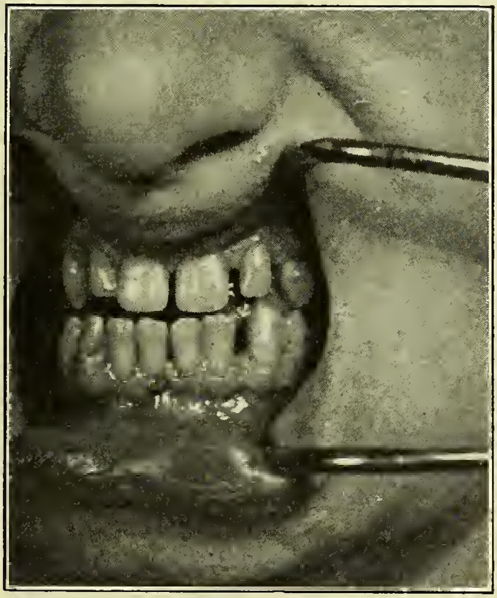


FIG. 184.—Gingival recession and festooning of lower right central incisor in young individual.

Second.—Serumal calculus originating from the blood in cases of inflammation, depositing in the gingival crevice and in pyorrheal pockets on the side of the roots.

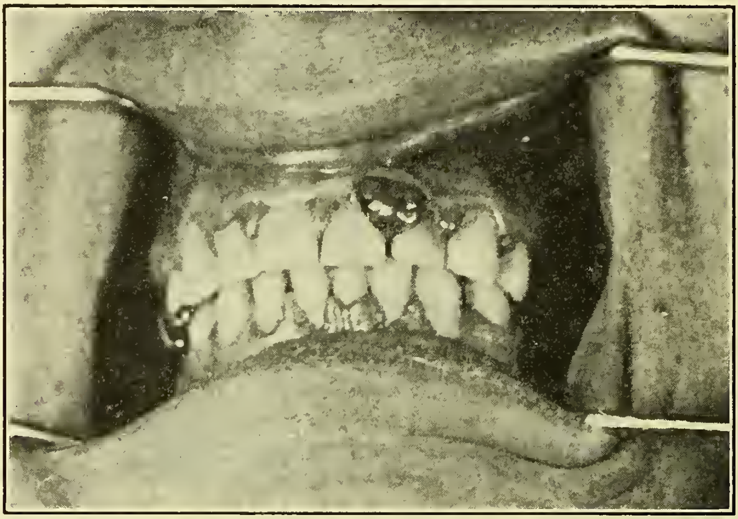


FIG. 185.—Localized gingival hypertrophy due to irritation. With curettage the growth disappeared. (Courtesy of Dr. Samuel C. Miller and Journal of Dental Research.)

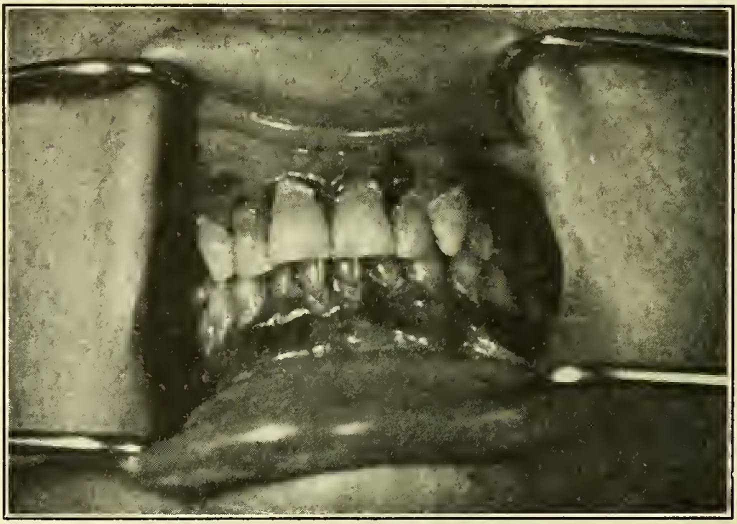


FIG. 186.—Scorbutic gingivitis.

Third.—Food debris of recent origin or fermenting or putrefying.

Fourth.—Dead epithelial cells exfoliated from the mucous membranes and present on teeth and soft tissues.

Fifth.—Bacterial plaques producing "spot acidity" and caries of the teeth.

Sixth.—Mucinous films on any tooth surface.

Seventh.—Green stains in the mouths of children.

Eighth.—Chromogenic bacterial stains, green, brown, or reddish.

Ninth.—Tobacco, tea, coffee, and medicinal stains.

Adequate mastication of coarse fibrous foods would largely eliminate these deposits and maintain the integrity of the soft tissues, but our modern civilization with its soft, pappy type of diet, low masticating habits and efficiency necessitates their artifical removal by dentist and patient and stimulation of the gums through the use of the brush and other measures.

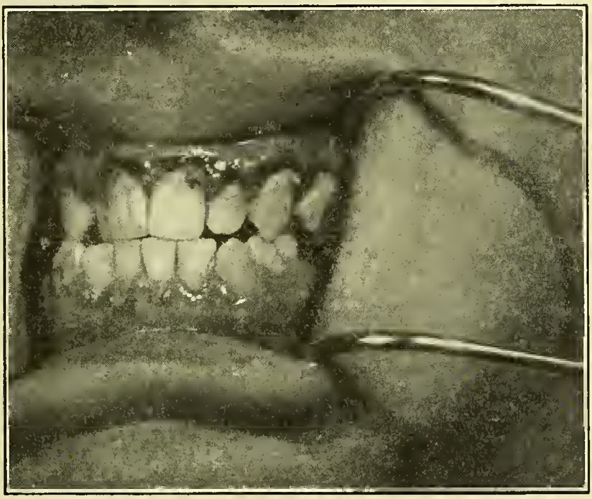


FIG. 187.—Congestion of gingival margin due to lack of hygiene. (Courtesy of Dr. Sidney Sorrin.)

Since these concretions and deposits are intimately concerned in the production of caries, gingivitis and pericementoclasia, the disturbances. the prevention of which we are largely concerned in this discussion, the importance of their thorough removal cannot be over-emphasized (Figs. 182, 183, 184, 185, 186, 187).

Far-reaching Effects of Deposits, Concretions and Apoxemena.—The *local results* of these deposits are far-reaching in character and may ultimately produce caries, fetid breath (halitosis), gingivitis, various forms of stomatitis, pericementoclasia (pyorrhoea alveolaris), pulp diseases, alveolar abscess, granuloma, pericementitis, osteitis, periostitis, osteomyelitis, bone necrosis and diseases of the antrum.

The *secondary effects* arising from the deposits and septic conditions in the mouth may be classified as follows, viz.:

First.—Throat affections; such as tonsillitis, pharyngitis, laryngitis, angina, diphtheria, abscess of the cervical glands.

Second.—Infections of the middle ear and otalgia.

Third.—Diseases of the eye; such as iritis, conjunctivitis, keratoscleritis, optic neuritis, strabismus, amblyopia, glaucoma, paralysis of accommodation, spasms of the muscles of the lids, paresis and many others.

Fourth.—Diseases of the stomach, intestines, respiratory apparatus and viscera; such as dyspepsia and indigestion, gastritis, constipation, diarrhea, abscess of the liver, pneumonia, bronchitis, tuberculosis and many others.

Fifth.—General constitutional disturbances; such as lowered vitality, anemia, gout, rheumatism and the diseases of sub-oxidation as well as abscesses, septicaemia, pyaemia and septic infections in general.

Sixth.—Reflex nervous disorders of the eye, ear, face and far-distant parts.

Seventh.—Lowered mental vigor, especially in children, as well as chorea, neurasthenia and epilepsy.

Infections in the mouth may travel to distant parts by way of the blood, the lymphatic vessels and glands, along the mucous tracts (eustachian tube, etc.) the respiratory tract (inhalation), digestive tract (deglutition), fascia of muscles and by continuity of tissue.

The development of vicious temper, untruthfulness, incorrigibility, degeneracy, melancholia and criminal tendencies, particularly in children are *psychological effects* which have been traced directly to the presence of inflammatory and septic conditions of the mouth.

Removal of Deposits and Concretions (Odontexesis).—Various types of instruments have been designed for removal of these deposits; such as scalers, files, planes and curettes. The files of D. D. Smith and Towner, the Thompkins, Buckley, Logan and Younger scalers, the planing instruments of Carr, James, Bunting and Hartzell are all well known types.

The McCall Prophylactic Instruments.—The McCall set of scalers and curettes (Figs. 188 and 189) adequately fulfill the requirements of the modern prophylactic specialist and periodontist, consisting of blunt pointed probes for exploring the subgingival tissues, a prophylactic chisel for the removal of gross deposits on proximal surfaces, several sickles, straight and rights and lefts for use on labio- and linguo-approximal surfaces, labial, lingual and posterior hoes and curettes for use subgingivally and in pockets. In the use of these instruments great delicacy of touch is required in order to detect subgingival deposits obscured from view. They should be lightly held with a modified pen grasp and a firm rest should be obtained on an adjacent tooth or surface in the same jaw being operated upon by means of the second or third fingers. The instrument should not be manipulated by extension and flexion of the fingers, which would produce tiring and cramping but rather by movements of the wrist or forearm in the arc of a circle. In this manner, delicacy of touch is maintained for detection of deposits while at the same time the force necessary for their removal may be utilized over long periods of time without tiring. Many of the instruments of the McCall set are designed for two point contact, one contact being the blade, the other point being on the shank, this serving to give the operator better control of the instrument during the act of planing and preventing the tendency to damage the tooth surface by nicking it with the sharp blade.

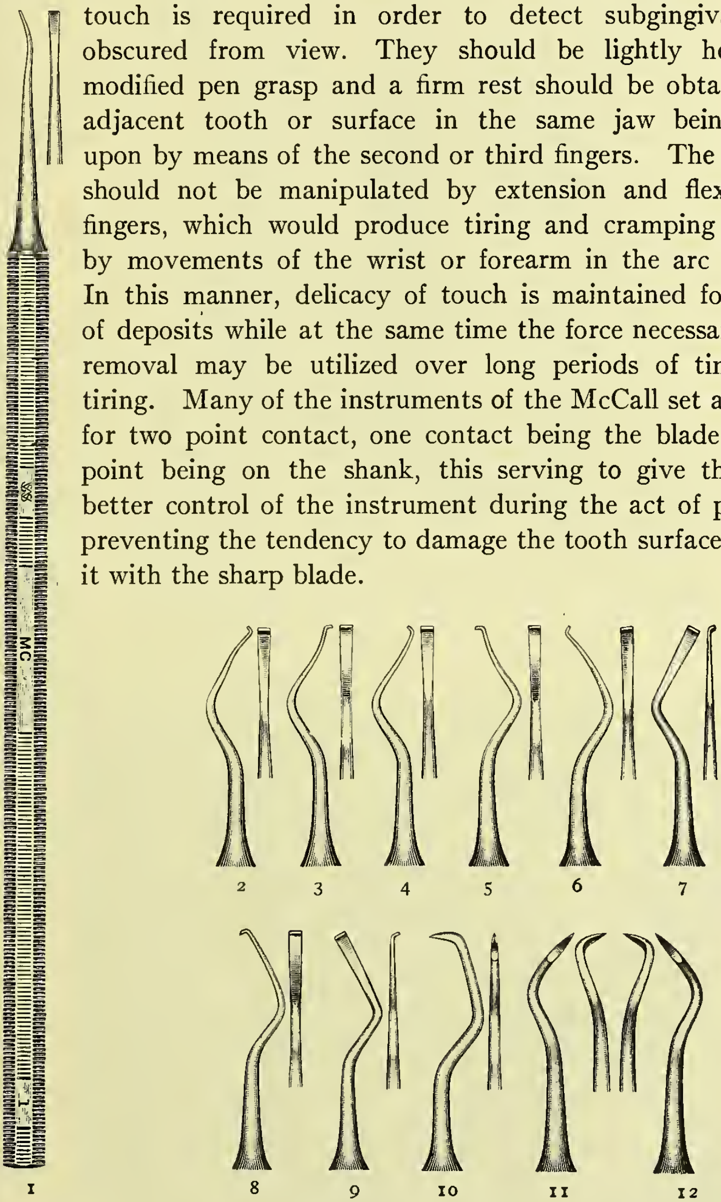


Fig. 188.—McCall Scalers.

In the use of this set of instruments (Figs. 191 to 200), the *prophylactic chisel*, number one, usually is first employed for removal of gross

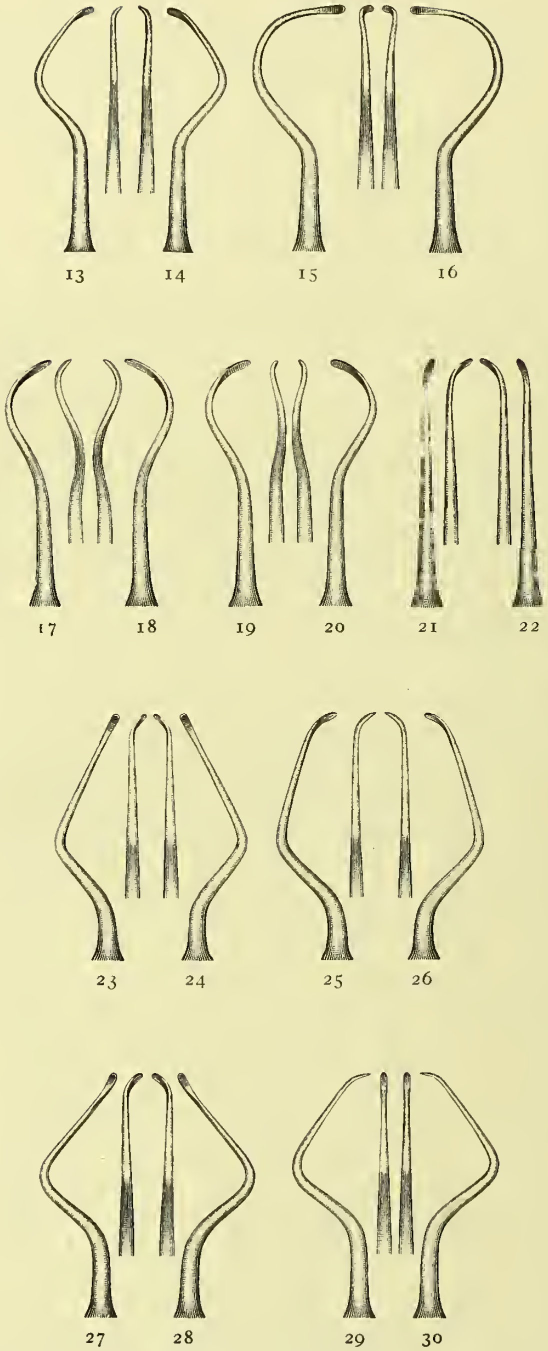


FIG. 189.—McCall curettes.

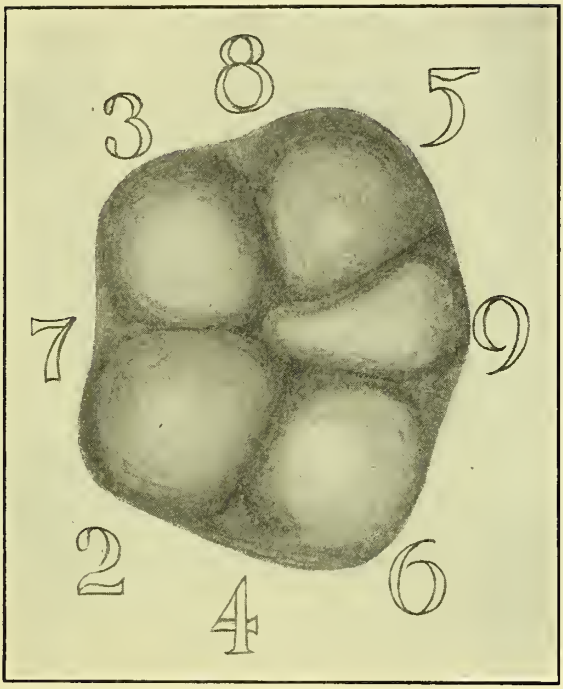


FIG. 190.—Use of McCall scalers on posterior teeth as advocated by some. The numbers indicate the numbers of the instruments used.

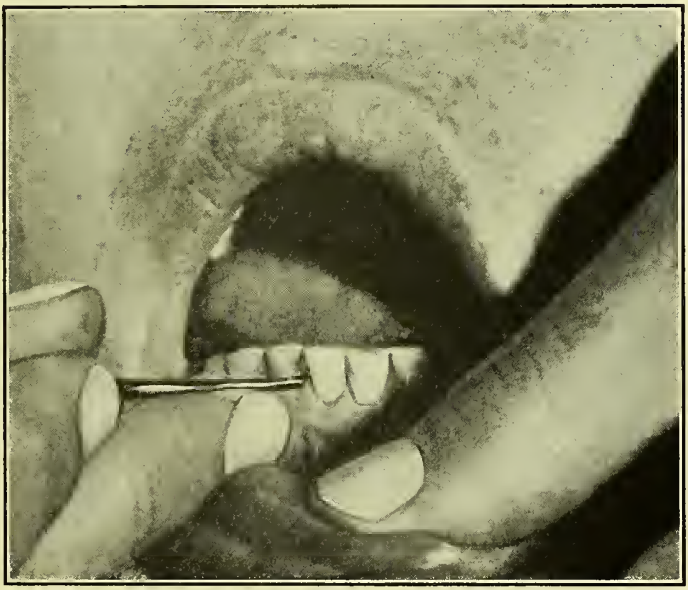


FIG. 191.—Use of anterior prophylactic chisel (McCall No. 1.) Used mainly on lower anteriors, with ball of 3rd finger as finger rest and protecting cushion. Instrument cannot go further than tissue cushion of the finger pad will allow. For proximal surfaces of anteriors only.

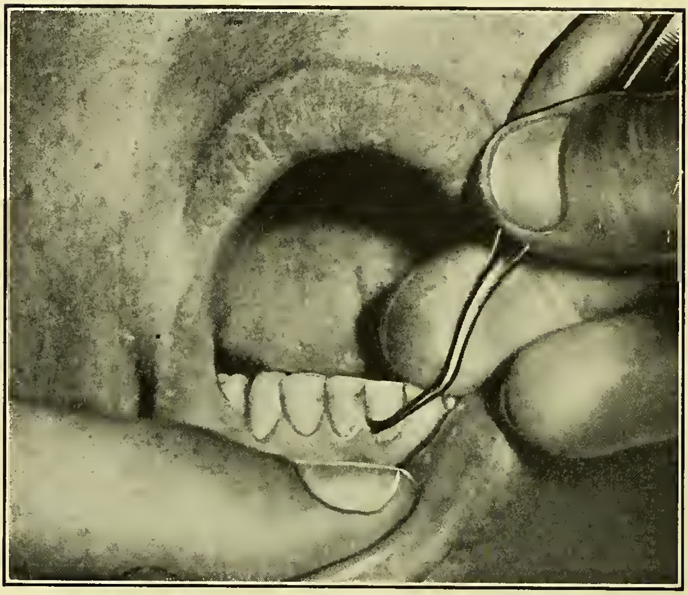


FIG. 192.—Use of anterior sickle (McCall No. 10). Keep finger rest on incisal edge as near as possible to the tooth being worked on. Both edges of sickle are sharpened. Used for proximo-labial and proximo-lingual angles of anterior teeth.

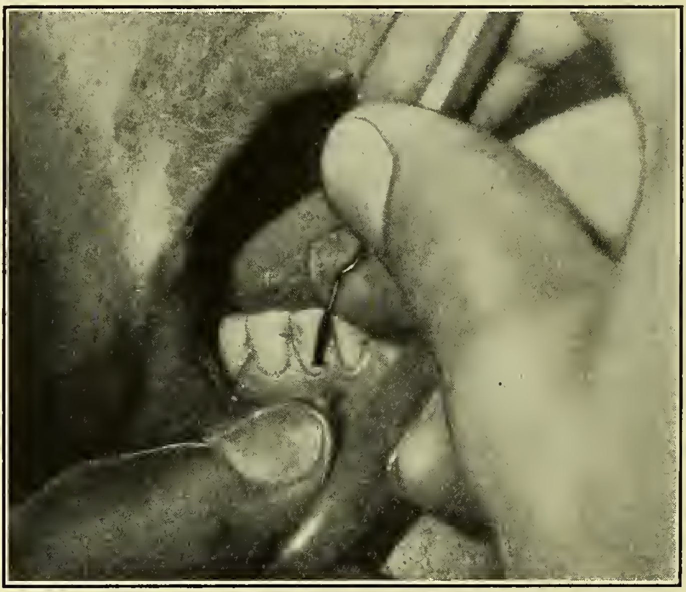


FIG. 193.—Use of labial hoes (McCall No. 2 and 6). These are specially constructed to give two point contact (blade and shank come in contact with the tooth). Specially suited for labial surfaces of anteriors, both upper and lower and for mesial of posteriors.

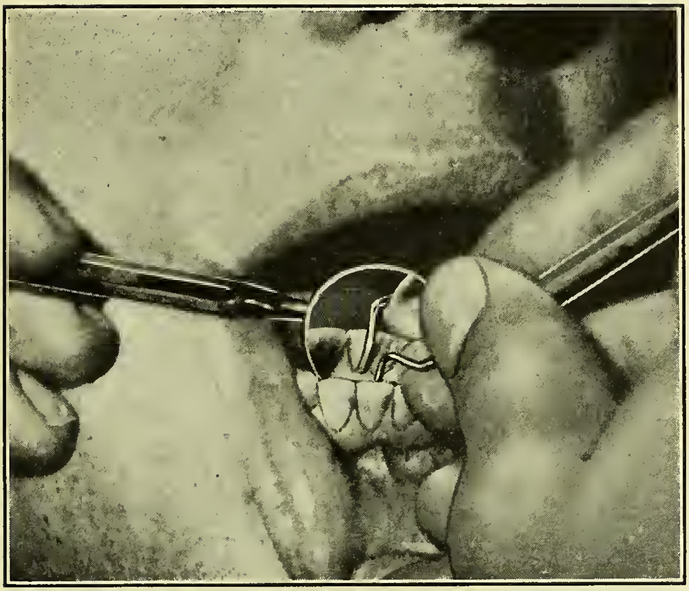


FIG. 194.—Use of lingual hoes (McCall No. 3 and 5). Shank is especially bent to give two point contact. Can be used on lingual of anteriors and disto-buccal and lingual of posteriors.

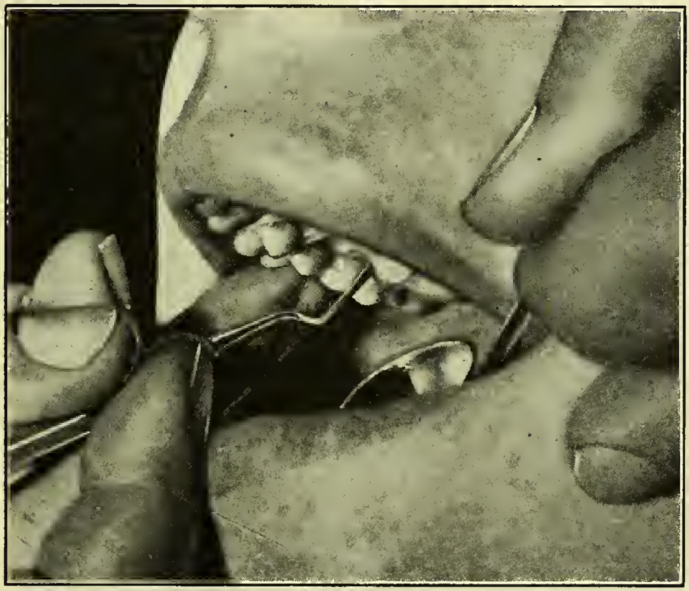


FIG. 195.—Use of posterior hoe showing position on lingual of upper posteriors (McCall No. 7 and 9). These instruments have a binangular bend of the shank to allow proper approach for the buccal and lingual of the posterior teeth. Finger rest should be as near as possible to the tooth being worked on.

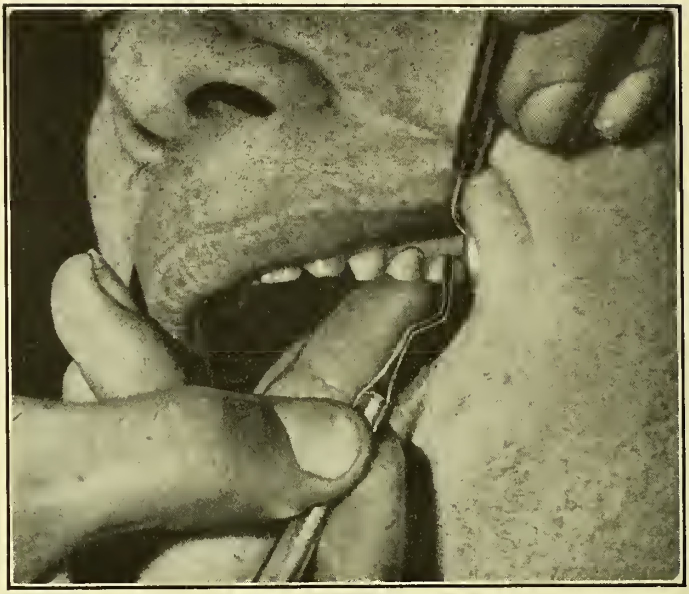


Fig. 196.—Use of the posterior planes (McCall No. 7 and 9) on the buccal. The No. 7 and 9 instruments can be used interchangeably, the instrument used on the buccal on one side becoming a lingual instrument on the other. Can be used on both upper and lower bicuspids and molars.

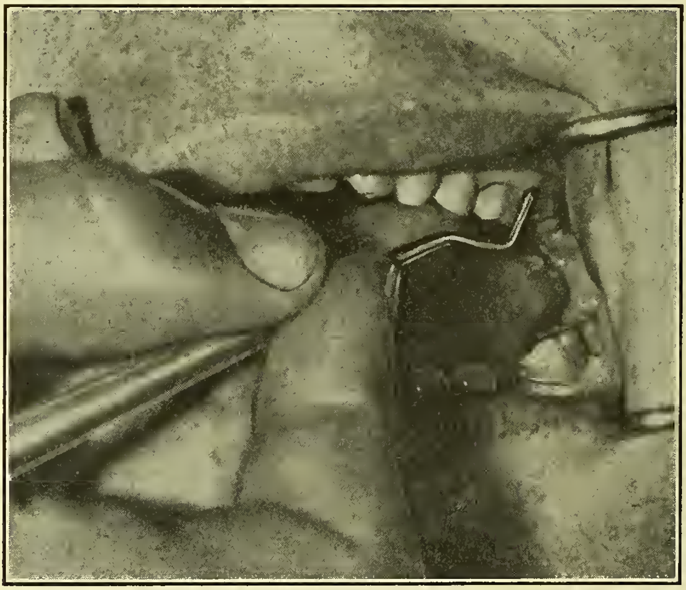


Fig. 197.—Use of posterior sickles (McCall No. 11 and 12). This pair of instruments is similar to the anterior sickle (No. 10) except that the shank is bent for posterior adaptation. It is used for the proximo-buccal and proximo-lingual angles of the posterior teeth.

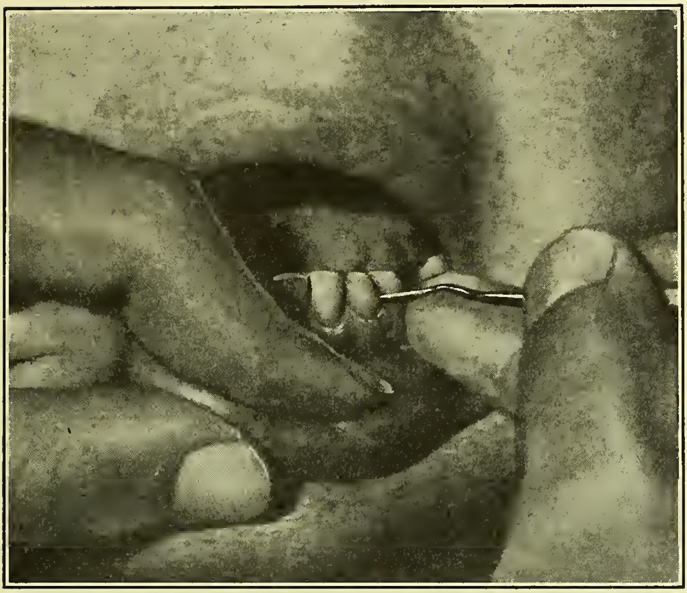


FIG. 198.—Use of mesial hoe for posterior teeth (McCall No. 4). This instrument can be used on all posterior teeth either from the lingual or buccal approach.

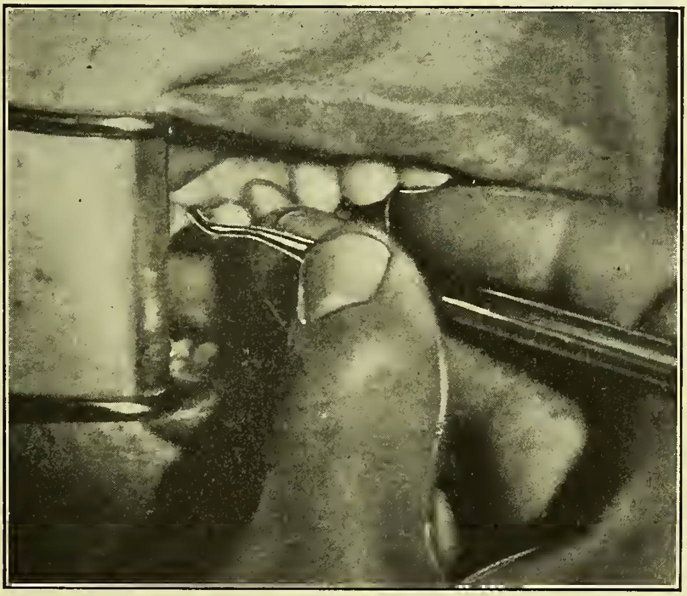


FIG. 199.—Use of distal hoe for posterior teeth (McCall No. 8). This instrument can be used on the entire distal surface for the bicuspids and molars. It is insinuated between the interproximal papilla and the tooth surface below the contact point.

deposits on the proximal surfaces of the anterior teeth. It is operated at right angles to the long axis of the tooth, being inserted between the marginal gingiva and the dentino-cemental junction and operated with a push cut. The *sickles*, number 10, 11, 12 consisting of one straight and a right and left also are utilized for the removal of gross deposists, the straight instrument (No. 10) on the labio- and linguo-approximal surfaces of the anteriors and the right and left (Nos. 11 and 12) on the same surfaces on the posteriors. The blades are sharpened on the sides as well as on the edge for use on both mesial and distal surfaces. The *labial hoes*, numbers 2, 4 and 6 are especially designed for two point contact and are used on the labial surfaces of the anterior teeth and on the mesio-buccal and mesio-lingual surfaces of the bicuspids and molars. The *lingual hoes* numbers 3 and 5 (also two point contact instruments) are used on the lingual surfaces of the anterior teeth and the disto-buccal and disto-lingual surfaces of the posterior teeth. The *posterior hoes*, numbers 7, 8 and 9 are used on the posterior teeth, number 7 and 8 on the buccal surfaces and number 9 on the distal surfaces.

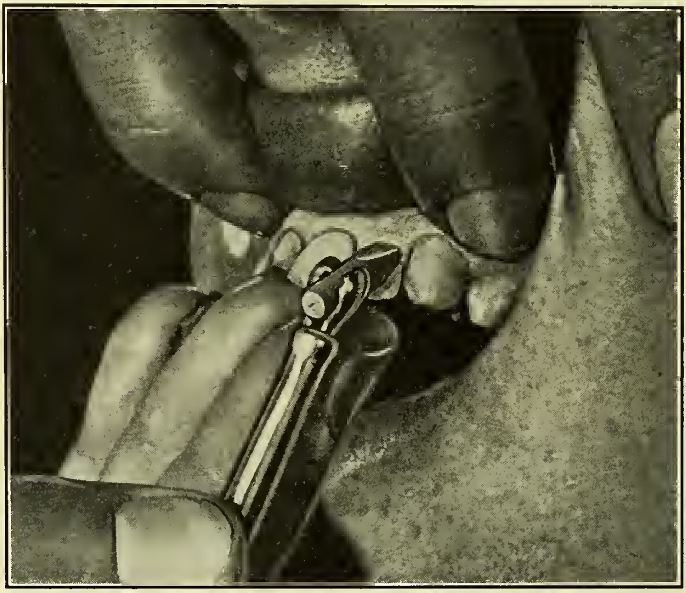


FIG. 200.—Use of porte polisher (Ivory Universal). Finishing up of the tooth surface above the gum line should be done with polishes and an orange wood stick (wedge shaped). This porte polisher is used with a rocking motion with a burnishing effect. It should be brought against the gingiva for tissue stimulation.

The *curettes* of the McCall set (see Fig. 189) are employed for delicate scaling in inaccessible localities, sub-gingivally and for smoothing and polishing the cementum. The shanks are delicately planed, the blades are sharpened on the sides and rounded at the point. They are used with both a push and pull motion. The *anterior* curettes numbers 21 and 22, are used in shallow pockets on anterior teeth. The *anterior-bicuspid curettes*, numbers 13 and 14 are applicable on labial and lingual surfaces of anteriors and bicuspids, while the *molar curettes*, numbers 15 and 16, are larger in size for use on molar teeth. Numbers 17 and 18 are *universal curettes* for any locality, while numbers 23, 24, 25 and 26 are *deep pocket curettes* for anterior teeth. Numbers 27 and 28 are for similar use on posteriors.

Scaling and Curetting.—Great care should be used during the scaling process to avoid injury to enamel, cementum and gingival tissues. All instruments should be kept sharp and the Arkansas stone should be conveniently placed on the operating table for this purpose. A definite routine should be observed so that the operator may be assured of complete and thorough removal of deposits from all surfaces. Use of the modified pen grasp as adopted by periodontists, proper rests or fulcrums, two point contact, when the instrument is so designed, and movement of the instrument by means of the entire hand or hand and arm, rather than by the fingers will lead to efficiency without strain in operating. All operative procedures should be done under aseptic precautions and with as little pain as possible. Instruments should be sterilized preceding the operation and may be frequently dipped in a soothing and antiseptic solution throughout the procedures. They should be frequently wiped on a sterile napkin and the patient should frequently rinse the mouth in an antiseptic solution. The removal of deep sub-gingival deposits from the surface of roots is designated by periodontists as *apoxesis;* the various types of substance removed from this locality being termed *apoxemena*. In cases of this type, it is a mistake to undertake too much work at one sitting. Thorough apoxesis of the mouth at a single sitting is inadvisable or impossible. In these cases, removal of apoxemena from a single locality or one side of the mouth would be advisable rather than from the entire upper or lower jaw. This would allow the use of another locality or the other side in chewing in case of discomfort following the operation.

Polishing.—After thorough scaling or apoxesis the teeth should now be highly polished by wood points in the porte polisher (see Fig. 200) and the gums stimulated by the same means. The action of the porte polisher should be toward the gingiva and it should be assisted by the use of flour of pumice or triple X silex, followed by oxide of tin powder. Where the tooth surfaces are markedly roughened and mucinous plaques are excessive, the flour of pumice will be advantageous. For ordinary cases, triple X silex will offer a happy medium. Either of these powders, placed in a medicament cup and moistened with a disclosing solution will be effective, the disclosing solution staining bacterial and mucinous plaques and bringing them into view. In extreme cases, Young's or Davis' rubber polishing cups in the engine will be effective (Fig. 201). However, they should be followed by the action of the porte polisher and the enamel should be given a polish such as nature provided in the mouth. The formula of Skinner's disclosing solution is as follows, viz.:

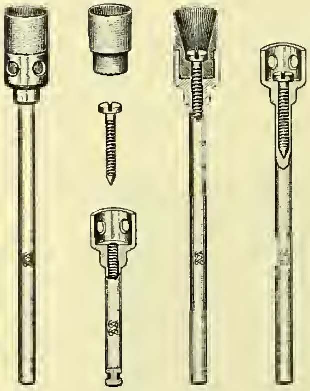


Fig. 201.—Davis polishing cups and mandrels.

Iodin crystals	gr. 50	(3.3 Gm.)
Potassium iodide	gr. 15	(1.0 Gm.)
Zinc iodide	gr. 15	(1.0 Gm.)
Glycerine	ʒ 4	(16.0 Cc.)
Water	ʒ 4	(16.0 Cc.)

For cleansing the proximal surfaces, ribbon dental floss dipped in the pumice flour or silex should be used. Care should be observed to avoid injury to the soft interproximal gum tissues in its use. It should be carefully pressed between the contact points by a slight buccolingual motion and then passed carefully over the proximal tooth surfaces until they are polished.

In certain cases presenting evidence of highly septic processes, the usual oral prophylactic measures herein described may be augmented by the application of special antiseptics. In widespread caries the use of metaphen and hexylresorcinol solution S.T. 37, as advocated by Bunting, may be used for the destruction of the aciduric type of organisms concerned as previously mentioned in the section on caries prevention. In cases of widespread periodontal and Vincent's infection, acriflavin in 1% solution, hexylresorcinol or oral perborate, flavored may be used to assist the routine prophylactic treatment. Gentian violet solution also is effective in widespread infections.

Personal Care of the Mouth.—Patients should be carefully instructed as to the importance and proper methods of maintaining the cleanliness and health of the mouth, and their bearing on the promotion of the hygiene of the entire body. The use of the tooth brush, dentifrice and floss silk should be demonstrated in the mouth with the patient seated in the chair, holding a mirror, so that he may intelligently observe the necessary procedures. It must be explained to him that not only must the teeth be cleansed but that the gingival tissues must be stimulated and hardened through proper massage of the brush (Figs. 202 and 203).

If the gums are healthy, they will appear pink and firm and will present well formed festoons tightly hugging the necks of the teeth. Changes in form and color are the chief diagnostic signs of peridental disturbance. The proper use of the brush should bring about a hypertonic condition of the connective tissue fibers, a thickening of the epithelial covering and a normal circulation in the parts, thus restoring or maintaining a healthy pink color and raised tissue resistance. A reddish color will indicate hyperemic and inflammatory conditions, while blueness will indicate partial stasis.

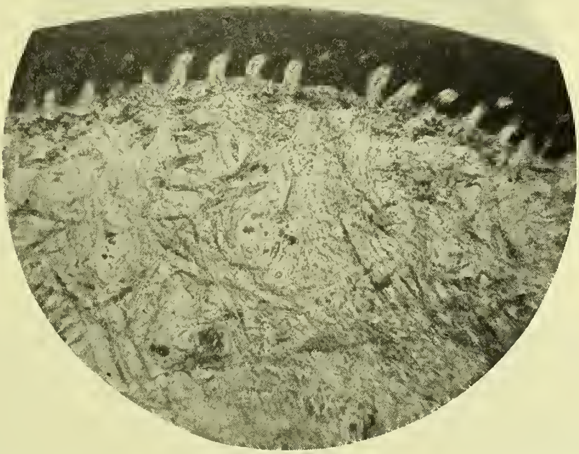


FIG. 202.—Alveolar mucosa, showing thin stratified squamous epithelial covering (dark area above) and interlacing connective tissue fibres below, which bind it to the periosteum. (Courtesy of Dr. Harold K. Box.)

Numerous methods for the use of the brush have been advocated. It is only necessary to mention those of Fones, Rhein, Hartzell and Barnes. All authorities are agreed that the old method, consisting of a mesio-distal stroke across the tooth surface is productive of tooth brush abrasions and recession and destruction of the marginal gingiva, and consequently should be abandoned. The up and down stroke still has its advocates, while certain groups of practitioners still advocate the large circle or rotary stroke. The method here advocated is that

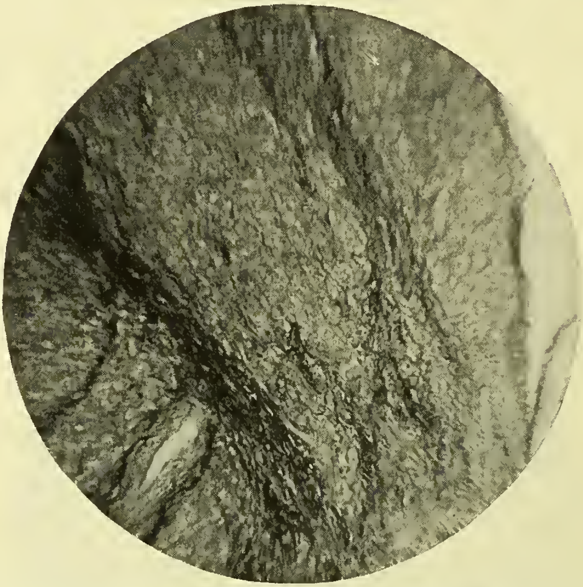


Fig. 203.—Base of gingival crevice to the right. Two bundles of principal fibres of pericementum extending into the marginal gingiva. (Courtesy of Dr. Harold K. Box.)

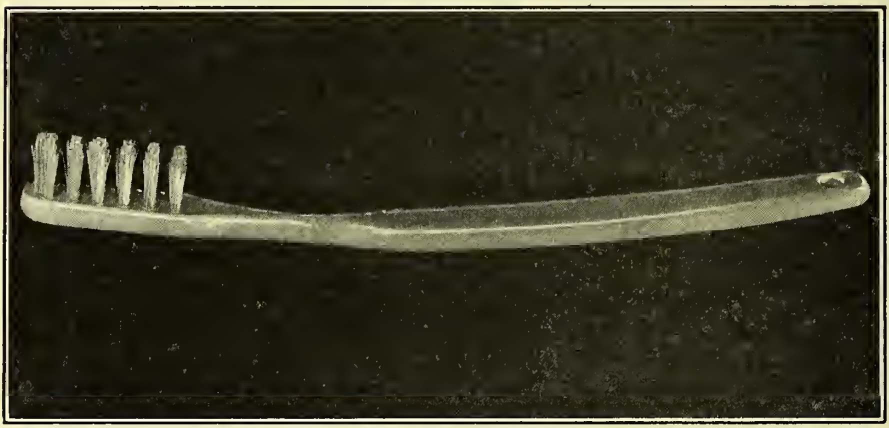


Fig. 204.—Type of brush used. A firm (preferably bone) handled brush with long stiff bristles of even length from heel to toe is used. At least 5 minutes morning and evening should be applied to tooth brushing. Two brushes should always be on hand so that one can be used mornings and one at bedtime to give 24 hours for drying out.

designed by Doctor W. J. Charters and somewhat modified by Doctor Paul Stillman and Doctor John O. McCall.

The brush should not be over one inch in length from heel to toe and about three-eights of an inch wide with long bristles arranged in tufts widely separated, the top of the tufts being saw shaped (Fig. 204). The working surface should be straight, not curved, since it has to be used both on the convexity of the outer surfaces and the lingual concavity of the same arch. The handle should be curved to give convenient access to all localities and should be about seven and one-half inches in length.

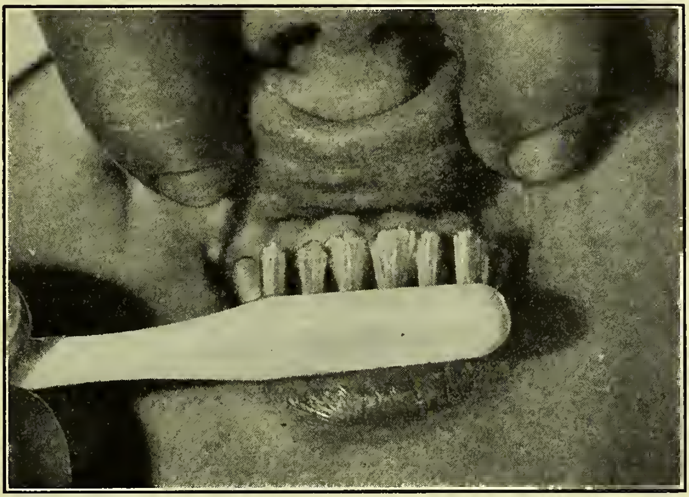


Fig. 205.—Position of brush for labial of upper anterior teeth. Brush is held with bristles on angle of 45° with the long axis of the tooth and pressed firmly against the marginal gingiva. The handle is then swayed or vibrated from side to side without moving the points of the bristles and brought down with a sweeping motion on the tooth surfaces.

Method of Using the Brush.—Place the brush at a forty-five degree angle to the surface of the teeth with the bristles extending about 3 millimeters on to the marginal and cemental gingiva. Care should be taken to avoid piercing the gum with the points of the bristles. Pressure should be produced by the sides, not the ends of the bristles. Sufficient pressure is now produced to cause a blanching of the gingiva, which may be seen in the mirror by the patient, when the brush is swayed from side to side with a slight vibratory movement without moving the bristles from their contact with the gums, thus forcing the bristles further into the interproximal spaces. With a continuation of the vibratory movement, the brush is now slowlycarried with a sweeping motion over the tooth surface toward the incisal or occlusal surface. This movement is repeated several times, when the brush is moved over to the next embrasure and the same procedure is repeated here, continuing in this manner on labial, buccal and lingual surfaces until the entire arch and all embrasures are thus treated. The V shape of the embrasures crowds the bristles of the brush into the interproximal spaces and on to the marginal and cemental gingiva. Every embrasure should be entered from both labial or buccal and lingual surfaces, the entire area of marginal and cemental gingiva should be massaged and all tooth surfaces, however inaccessable, should be swept. Next the occlusal surfaces should be cleansed by forcing the bristles into the pits and fissures and giving a slight rotary movement, repeating the procedure until sure of complete cleansing. With narrow arches, when it is inconvenient or impossible to place the brush horizontally on the lingual aspect of the anterior teeth, it may be placed length-wise or perpendicularly and the correct motions accomplished. This method will be found very effective in cases with orthodontic appliances in position. The mouth may be forcibly washed at frequent intervals throughout and at the end of the cleansing operation with a normal saline solution to flush out debris. The brush also may be frequently dipped in the salt solution. In no instance should the brush be carried high on the gingiva on account of the danger of producing

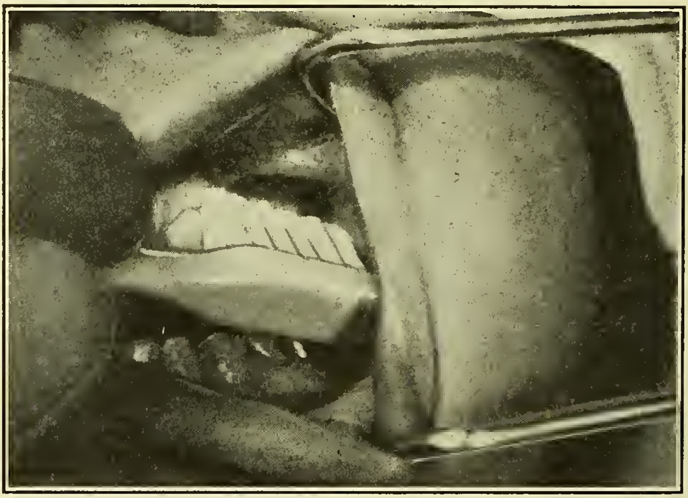


Fig. 206.—Position of the brush for gum massage on the buccal of upper left side. Note the angle of the brush and that bristles are pressed horizontally against the tissue, and not abruptly bent.

injury to the areolar mucosa. Following the use of the brush, the interproximal spaces may now be further cleansed with ribbon dental

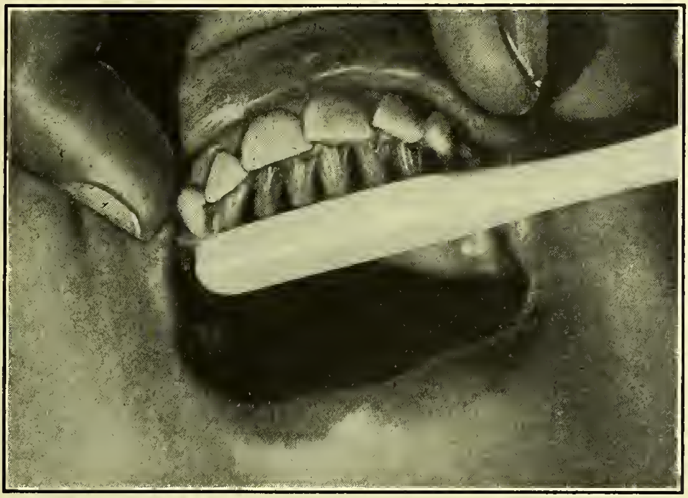


Fig. 207.—Position of brush on the lingual of upper anteriors in a wide arch. Where the arch will accommodate the width of the brush head this method can be used. Otherwise either one or two tufts of bristles can be left out, or the brush can be turned, as in Fig. 208.

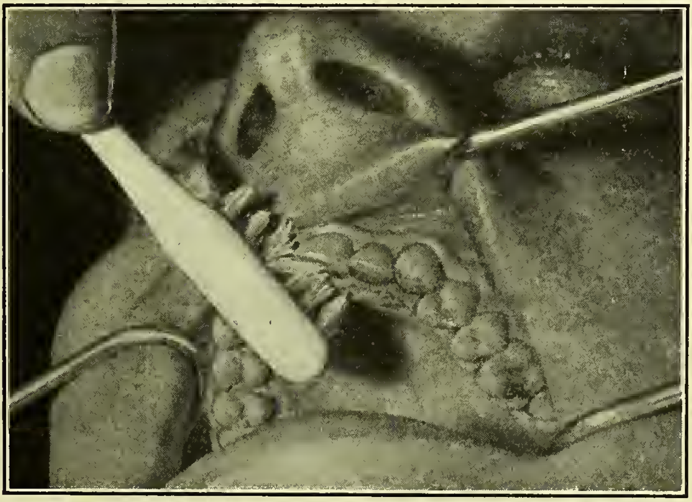


Fig. 208.—Position of brush for lingual of anteriors in a narrow arch. The brush is turned and the brush head is split allowing about 3 sets of bristles lingually. The pressure is brought forward and the brush is slowly vibrated against the teeth.

floss, avoiding injury to the interdental papilla. The tongue, if furred, may be carefully scraped with a tongue scraper. The entire operation, when performed by the patient, should be timed with the watch or sand glass and should require from three to five minutes as a minimum.

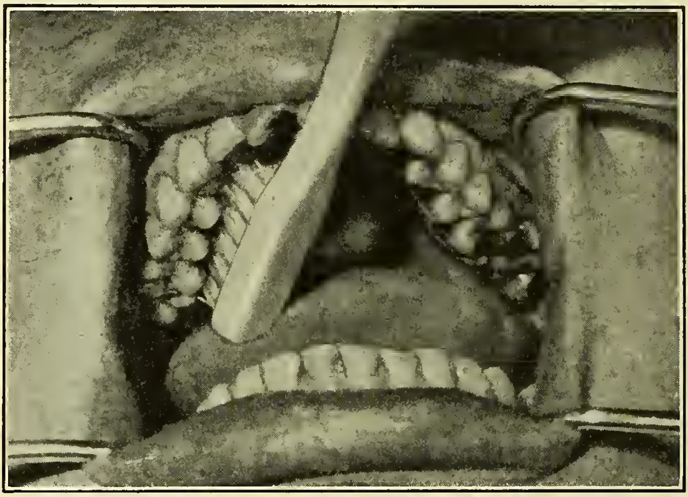


FIG. 209.—Position of the brush for the lingual of the upper posteriors. The method of procedure is the same for the lingual as for the buccal surface.

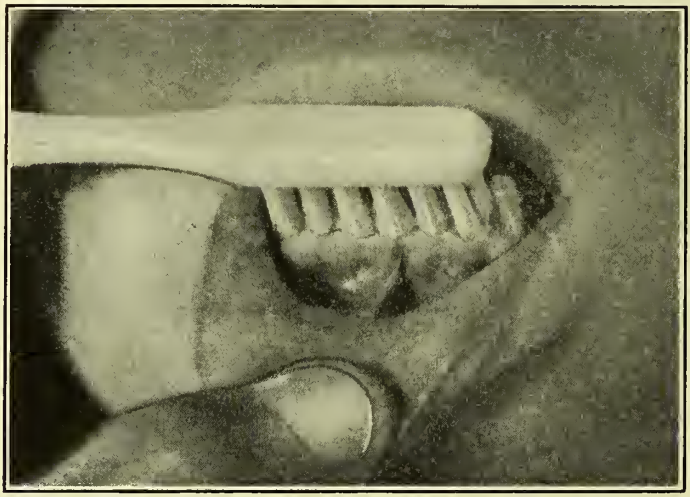


FIG. 210.—Position of brush for labial of lower anteriors. This picture illustrates well the blanching which should be produced by the labial pressure of the tooth brush. The blanching and succeeding redness is due to the forcing out of old blood and the influx of new healthy blood.

The cleansing operation should be performed three times a day and before the mirror in order that the patient may observe and study the correctness of the technique and note the changes in the soft tissue resulting from the systematic massage. The pressure brought to bear on these tissues forces the blood from the arteries into the veins, causing a blanching of the part, which, on the relief of the pressure, changes to

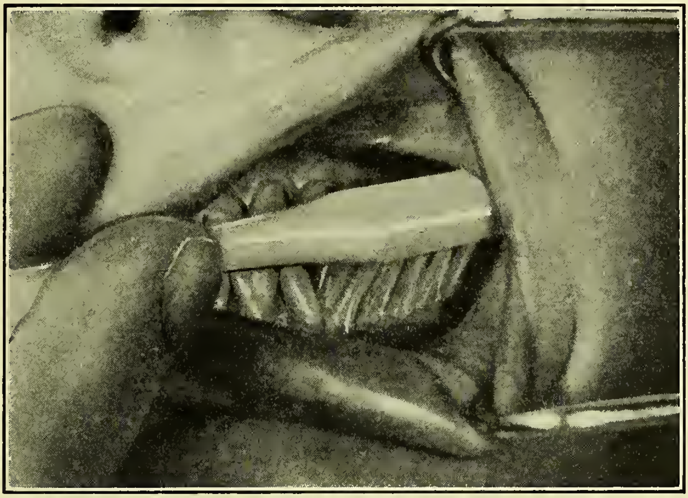


FIG. 211.—Position of toothbrush on buccal of lower posteriors. Here we again see the 45° angle at which the brush should be held to obtain proper massage of the gingivae and cleansing of the teeth.

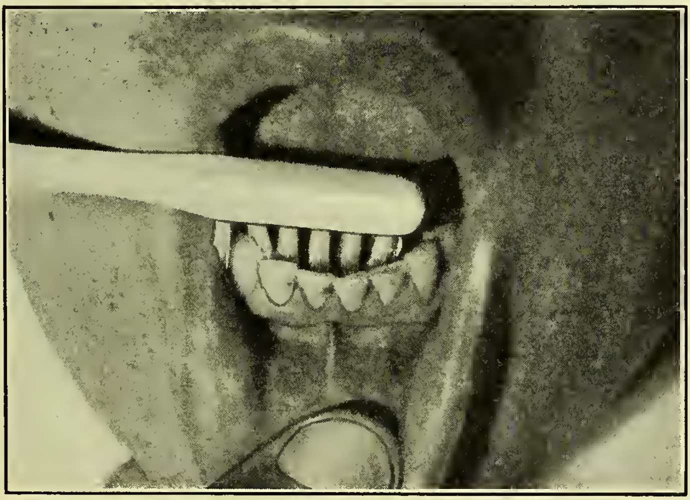


FIG. 212.—Position of brush for lingual of lower anteriors in a wide arch. The brush is held similarly to the position used for the upper linguals except that the bristles are vertical because of the labial inclination of the lower anterior teeth.

a bright red color due to a temporary arterial hyperemia. The tissue then assumes a pink color, the duration of which depends on the state of the tissue being stimulated and the frequency and correctness of the technique employed. Proper use of the brush also acts as a scavenger of the

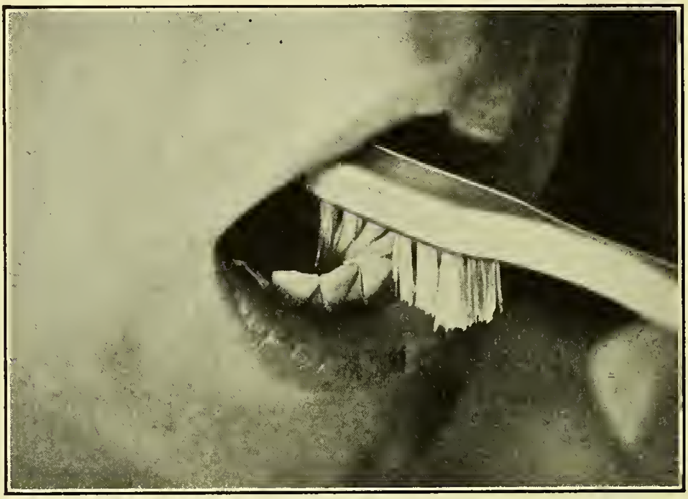


Fig. 213.—Position of the brush for the lingual of the lower anteriors in a narrow arch. The inclination of the teeth is such that the brush should be held in a horizontal position in order to produce the 45° angle. For a wide arch the brush may be turned in a similar manner to the upper as shown in Fig. 207.

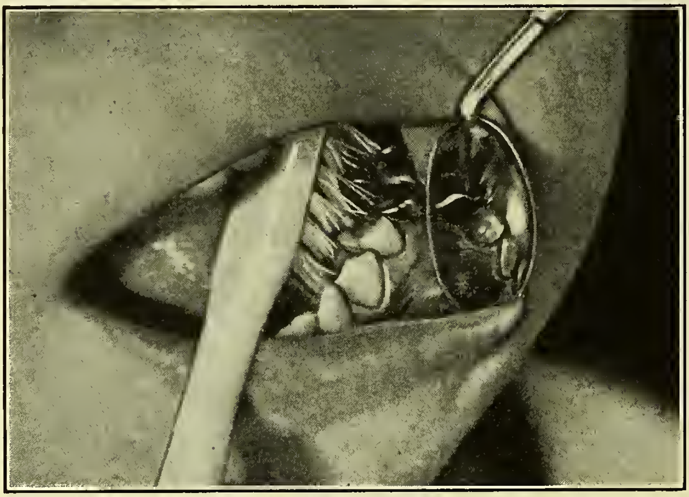


Fig. 214.—Toothbrush position for linguals of lower posterior teeth. Note how the bristles crowd into the embrasures as the brush is brought up toward the occlusal surface. For cleansing the occlusal surfaces of the bicuspids and molars, the bristles can better be crowded into the grooves, (crowding the food out) or the surfaces can be scrubbed.

gingival crevice, since it expresses viscid secretions and foreign particles from under the marginal gingiva.

Use of Dentifrices.—Before we can intelligently discuss the question of dentifrices, it is first necessary to briefly review the important characteristics of the tissues on which the dentifrice is intended to act, viz.: the teeth and soft tissues and the fluids in which these tissues are bathed.

The tooth is normally covered by the enamel which has a comparative hardness of 5.5 to 5.7 and which contains a small percentage of living matter. In cases of receding gum, abrasion, erosin and caries, the normal enamel protective covering is lost and either the dentin or cementum is exposed, both of which are penetrated by canals containing living matter and which have a comparative hardness of 3.5 to 5. All of the tissues of the tooth act as dialyzing membranes and are permeable to stains, calcium ions, fluids and other substances. Pickerill has succeeded in passing graphite through the enamel, while Bunting, Price, Pickerill, and others have dialyzed calcium salts through it and increased its weight by this process. All of the tissues of the tooth are stainable by silver nitrate, anilin days and some colored dentifrices. The tooth, when first erupted, is comparatively soft and readily permeable, but increases in hardness and solidity through deposition of calcium salts, with age.

The gums cover the alveolar process and are attached to the teeth at the gingival line, rising from here in a thin, knife-like edge, which is very delicately constructed and subject to injury through mechanical and chemical irritation and trauma. Nature intended the gums to be subjected to stresses derived from mastication of coarse, fibrous foods, which have a stimulating and hardening effect on them. Imperfect mastication of soft foods results in loss of tone and lowered circulation and resistance in these tissues.

The teeth and soft tissues of the mouth are bathed in the salivary fluids, consisting of the saliva from the salivary glands and mucous from the mucous glands. Mixed saliva is about 995 parts water and 5 parts solids, the solids consisting of mucin, potassium sulfocyanate, ptyalin, sodium and potassium chlorides, calcium, magnesium and sodium phosphates, and calcium bicarbonate.

The mixed saliva is amphoteric, having both an alkaline and acid reserve. Normal resting saliva has a hydrogen ion concentration of about 6.6 as an average, this varying in individuals at different times of the day and under various stimuli. Saliva as it flows from the salivary glands has an alkaline reserve predominating. In resting saliva acidity predominates, owing largely to the presence of CO_2 from the lungs.

With the Soresen Scale pH7 indicates neutrality, below 7 indicates acidity, above 7 indicates alkalinity.

Ptyalin, the amylolytic salivary ferment, transforms starch into maltose and dextrose and acts best in an alkaline medium. The mucin is present in the saliva as alkaline potassium mucinate and acts as a lubricant for the food and teeth, just as oil does to a motor. When it comes in contact with the acids of fermentation it combines with them, thus helping to neutralize them and forming acid mucin which is deposited on the teeth in the form of a film. Mucin deposits at pH 4.58 and is redissolved at pH 5.23.

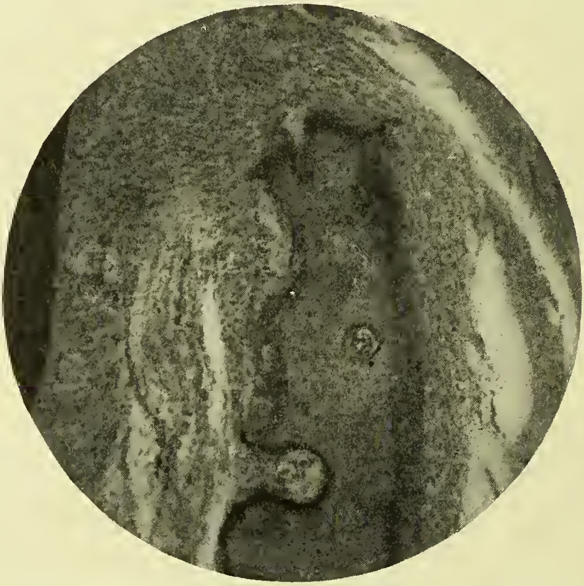


FIG. 215.—Alveolar rarefaction at alveolar crest. Dark area to the left is cementum covered by pericementum. Central area is rarefying bone showing an Haversian canal. (Courtesy of Dr. Harold K. Box.)

The recognized functions of the saliva are to act as a flushing agent in the mouth, to assist in the digestion of starch particles on the teeth through its amylolytic ferment, ptyalin, to lubricate the food and afford a protecting film against the acids of fermentation, through its mucin content and to moisten the bolus of food, so that it may be more readily masticated and swallowed. Also, it keeps the soft tissues of the mouth in a proper state of moisture for the performance of their functions and affords necessary moisture for the teeth to prevent them drying out and becoming too brittle. The work of Michaells, Marshall, Bunting, Pickerill, and Ruthrauff would indicate that also it has probably very important and hitherto unrecognized functions in the calcification and hardening of the teeth after eruption, through dialysis of its calcium and phosphatic content.

Types of Oral Conditions.—There are three general types of oral conditions with which the dentist comes in contact: *First.*—The type in which there is partial or complete immunity to caries, the teeth being of good structure with almost complete absence of calculus deposit and with the soft tissues firm and healthy.

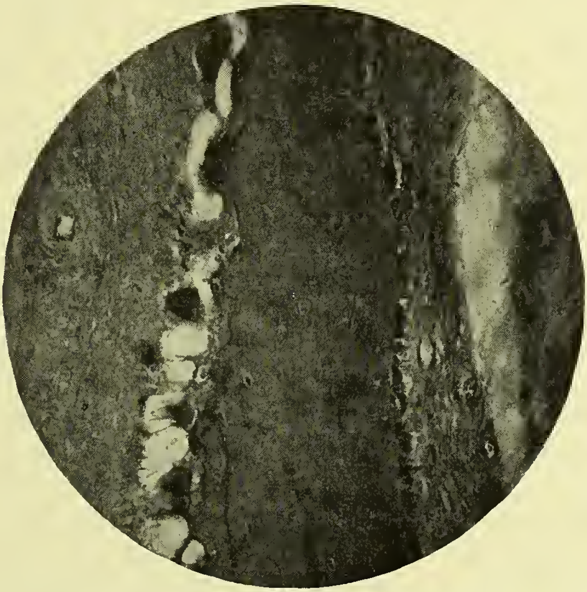


FIG. 216.—Multinuclear osteoclastic absorption of crest of alveolus. Alveolar crest in center, osteoclasts to left, osteoblasts to right. (Courtesy of Dr. Harold K. Box.)

Second.—The type in which caries is predominant, the teeth of poor structure and calculus comparatively absent, with little evidence of periclasia (pyorrhea alveolaris). Mono-calcium phosphate predominates in the saliva in caries susceptibility, while tri-calcium phosphate predominates in immunity.

Third.—The type in which the tendency to calculus formation is marked, the teeth of good structure, with predispositions to active periodontoclasia.

The first type is of course the rarest, the second is possibly the most frequent, being found largely in adolescence and early adult life; while the third is more often found in the middle and later periods of life. The factors concerned in the production of these three types are undoubtedly intimately related to the calcium metabolism of the body, affecting the structure of the teeth and soft tissues and the composition of the saliva, and the objective manifestations are entirely different. Is it rational, then, to prescribe a single dentifrice for all three types? Yet this is what is being done in the publicity material of many of the dentifrice manufacturers and by many men in the practice of dentistry.

Classification of Dentifrices.—Dentifrices, as at present manufactured, may be given a general classification into (1) alkaline, neutral, or acid; (2) saponaceous (soapy), or non-saponaceous; (3) proteolytic (protein digestive) or non-proteolytic; (4) amylolytic (starch digestive) or non-amylolytic. Classes three and four have recently almost entirely disappeared from the market.

Constituents of Dentifrices.—The principle cleansing agents in the alkaline preparations consist of one or more of the following substances, viz.: Talc, with a comparative hardness of 1; magnesium oxid with a hardness of 2; magnesium carbonate, hardness of 2.5; calcium carbonate, hardness 3 to 3.5; pumice, hardness 6. The principle cleansing agent in some of the prominent acid pastes is tri-calcium phosphate with a hardness of 4 to 5. The hardness of enamel ranges from 5.5 to 7, cementum and dentin 3.5 to 5. It would seem, then, that tri-calcium phosphate as a base is too harsh to be brought in daily contact with exposed cemental and dentinal surfaces, or even the enamel of soft, or deciduous, or malacotic teeth. Pumice and cuttlefish bone are constituents of some of the other preparations, the former for use in pyorrhetic and smokers' mouths. However, an examination of a large majority of the most prominent powders and pastes will reveal the fact that excessive grittiness is gradually being eliminated. Other constituents frequently found in the alkaline preparations are magnesium hydroxide, soap, glycerine or glycerite of starch, (pastes), sugar or glucose, alcohol, saccharin, essential oils, thymol, menthol, benzoic acid, boric acid, and sodium perborate.

Functions of Dentifrices.—The chief function of a dentifrice is to help to cleanse the tissues of the mouth and to assist in maintaining these tissues in normal condition without producing injury. Its formula should be as simple and contain as few ingredients as possible. It should not be highly medicated with antiseptics, astringents and strongly stimulating substances. The chief function of a dentifrice is to assist in the cleansing operation and not to medicate. There is no particular need for soap. The chief advantages claimed for it are its detergent properties, its power to depress the surface tension of liquids and thus to diminish the activity of bacterial life, and its power to penetrate the fatty coats of bacteria. However, since it is claimed that it hydrolizes in the saliva and forms caustic soda and free fatty acids, that it increases the adhesion of the film, reduces the salivary flow and increases the tendency to tarter deposition, its efficiency is of doubtful value. Certain manufacturers have advertised the incorporation of ferments or digestives in their preparations. One of these contains pepsin, a proteolytic ferment. U. G. Rickert has found that it requires 38 minutes to digest 24 hour plaques with this ferment, hence its value for this purpose is practically nil, although the manufacturers lay great stress on it. The efficacy of a formerly extensively advertised tooth powder is supposedly greatly increased through the incorporation of caroid, a ferment derived from the Carica Papaya and other tropical plants, and the manufacturers of another preparation were creating quite an impression on the minds of the credulous through demonstrations of the starch-digesting properties of their preparation which contains diastase, a ferment derived from germinating barley and other grains. Since the chief function of dentifrices is to assist in cleansing the mouth, the inclusion of substances of this nature, although probably good advertising, is unphysiologic and of very doubtful advantage. Some of these dentifrices are claimed to increase the ptyalin content of the salivary fluids through the action of certain constituents. If they do, which has not yet been proven, there is no particular advantage in this action, Pickerill to the contrary, since the function of ptyalin is to transform starch into sugar, which is only one step further in the manufacture of lactic acid in the presence of fermentative bacteria.

Certain manufacturers are still laying stress on the phenol coefficient of their preparations, as capable of destroying 80 to 90% of the flora of the mouth and greatly reducing the action of those remaining. Since the air is teeming with micro-organisms as are many substances entering the mouth, it is manifestly impossible to maintain the oral cavity in a sterile condition even if it were desirable. In addition to this, the partial reduction of the mouth flora is only temporary and necessarily accomplished through the action of drugs which must undoubtedly ultimately produce pathological effects on the soft tissues. Also, some of the mouth flora have important functions to perform, which functions would be interfered with if they were destroyed. An extensively advertized paste dispensed in two different strengths is supposed to be highly efficacious on account of its iodin content. Number two is supposed to be especially efficient as a bleacher to be used by smokers and those who do not give their mouths regular attention. An analysis of these two pastes did not show any free iodin, revealed a small percentage of iodides, and, so far as could be discovered, the chief difference in the formulae was greater abrasive power and the inclusion of more soap and flavoring in number two.

It is pleasing to note that artificial coloring matters have been gradually disappearing from dentifrices since the writer called attention to staining effects on tooth structure of some of them at the meeting of the American Dental Association in Cleveland in 1911,[1] a short while before the United States Pure Food Bureau took legal steps to prohibit the inclusion of similar substances in food stuffs. However, the manufacturers of some of these preparations still are artificially coloring them, supposedly either to improve their appearance or for the psychologic effect on the user. Although the emetin error was long ago exposed, some of the preparations still include emetin or ipecac in their formula. Potassium chlorate is contra-indicated for continued use in the mouth on account of its depressing and softening effect on the gums; yet, a well known tooth paste still contains a high percentage of this drug. The inclusion of many of the latter remedies mentioned in a preparation for use in the mouth several times a day may give rise to dangerous and unexpected complications if swallowed by children. Sodium chloride is being included in some of the formulae. It is at least harmless in the strengths being used but would probably be more efficacious if used alone. It is very mildly germicidal, a stimulant to the local capillary circulation and reduces congestion by ex-osmosis. It helps to keep mucin in solution and increases the action of ptyalin.

The use of glycerine in practically all dental creams seems to be a necessity, since no substitute has yet been found for it. This substance is a tri-atomic alcohol, a powerful de-hydrant and depletent. As a constituent of tooth pastes for continous use, especially in healthy mouths and in mouths receiving the careful attention as advised by modern periodontists, it is, if continuously used in high concentration, capable of producing injury to the soft tissues. Dental creams, owing to their convenient form, are, and undoubtedly will continue to be used by many of the laity in preference to powders. Many of them are probably producing very little injury in poorly cared for mouths, but will continue to be objectionable for the opposite types until some efficient and harmless substitute for glycerine is found. For this reason alone, the powder, regardless of its inconvenience in handling, is less dangerous if its formula does not contain more harmful constituents than glycerine.

Alkaline versus Acid Dentifrices.—Formerly, the principal functions attributed to dentifrices were the mechanical cleansing of the teeth, reduction in number and toxicity of the micro-organisms and the neutralizing of the acids of decay. In recent years, these ideas have been modified and through the work of Pickerill, Gies and others, it is believed by some that the important factors to be dealt with are the stimulation of the flow and alkalinity of the saliva, the dissolving of the mucin film, and the increase of the ptyalin content. Let us briefly consider these factors separately and discuss the available evidence as reported by various investigators.

Ptyalin.—Pickerill claims that eating acid fruits and the use of fruit acids increases the ptyalin content of the saliva more than ten times. Other well known writers claim that no dentifrice investigated by them increased or decreased the ptyalin in the saliva, except very slightly and then but for a short time. The ptyalin content varies in individuals and at different times of the day. It acts best in an alkaline medium, and acids destroy it. Sodium chloride increases its action while astringents reduce its activity. The action of ptyalin on hydrolized starches is to transform them into maltose and dextrose. Since maltose and dextrose are readily fermentable, through the action of bacteria, into lactic acid, it would seem that if the findings of Pickerill are correct and the ptyalin content is greatly increased, the use of fruit acids for this purpose increases the danger of caries production and attempts to increase its activity are manifestly illogical.

Increasing the Flow and Alkalinity.—The reaction of the saliva as it flows from the salivary glands is slightly alkaline. This reaction is not modified by stimuli, either acid or alkaline. However, an increased flow from these glands immediately becomes mixed with the resting acid saliva and, of course, increases its alkalinity. Salivary flow is increased by mastication, brushing the teeth with or without a dentifrice, psychic phenomena, essential oils, odors of foods, inorganic acids, pleasant flavors, paraffin chewing (most effective), fruit acids, alkalies and most foods. The resultant increase in the flow will obviously increase temporarily the alkalinity of the mixed saliva which is normally acid on account of its carbonic acid content, holding in solution mono-calcium phosphate which is also acid. This is a provision of nature to help maintain equilibrium. The salivary flow and alkalinity varies in individuals and at all hours of the day. It is increased during digestion and falls during the interim. Stimuli have been found to produce opposite effects in different individuals. Practically all dentifrices increase the flow and alkalinity of saliva for a short while. Both acid and alkaline dentifrices reduce the acidity for a period, in some individuals the acid being more effective, in others, the alkaline. Brushing without a dentifrice increases flow and alkalinity of the mixed saliva about as much as with the use of the dentifrice. In all instances the flow and reaction return to the normal in a very short while.

This is the evidence as far as the action of stimuli is concerned. Consequently we may conclude that there is no particular advantage to be derived from attempting to increase the flow and alkalinity of the oral fluids by artificial stimuli, except probably in special cases of diminished flow and volume with consequent increased tendency to caries. Undoubtedly, in average cases, repeated stimulation of the salivary glands would ultimately result in depression and salivary impoverishment.

Michaels has demonstrated that in all cases of immunity to caries the resting saliva is hyper-acid while in susceptibility it is hypo-acid. Marshall has corroborated his findings, stating that in caries there is high alkalinity and low acidity, and that in immunity the conditions are reversed. These findings are accepted by the majority of the scientific minds in the dental profession and indicate that the chemical reaction of mixed saliva is not concerned in, or particularly influenced by, the fermentation of carbohydrate debris on the teeth; but rather that caries is produced by *spot acidity* under the film or bacterial plaque, which acidity does not come in contact to a great extent with the oral fluids, owing to the interposition of the film. So, consequently, attempts to increase or maintain for long periods, the alkalinity of the mixed saliva are not only ineffectual as far as neutralizing spot acidity is concerned, certainly until the film is removed, but may actually do harm by increasing susceptibility to caries by reducing the acid reserve found by Michaels and Marshall to be co-incident with immunity. This acid reserve of the resting saliva is largely due to the presence of mono-calcium phosphate, (acid calcium phosphate) which is held in solution by the CO_2 acidity. When CO_2 acidity is reduced, there is increased tendency to the formation of alkaline tri-basic calcium phosphate which being insoluble is deposited on the tooth surface as calculus, and may possibly under certain circumstances be dialyzed into the enamel.

Removing the Mucin Film.—Mucin is in solution in the saliva as alkaline potassium mucinate. The presence of the sodium chloride constituent of saliva assists in holding it in solution. When contact is made with the acids of fermentation, it is precipitated as acid mucin in the form of a protecting film on the tooth surface, this helping to neutralize the local acidity. However, if fermentation is excessive, this protective action is soon lost through the production of more acid, which deposits under the film. In addition, micro-organisms, food debris, and calcium salts become entangled in it; hence the advisability of its occasional removal in order that fresh film may form, just as oil should be occasionally changed in a motor. Potassium mucinate may be precipitated by acids at pH4.58, but the acid mucin film on the teeth, having already been acted on by acids, cannot be further precipitated or dissolved by organic acids. It is soluble in strong mineral acids of weak concentration. However, it is claimed that weak organic acids do have a curdling effect which may assist in loosening the attachment of the film and facilitate its removal by the brush. The work of Jacques Loeb, Martin Fisher, and Vogt has demonstrated that the quantity of protein dissolved and the rate of its dissolving increases with the degree of alkalinity (within certain limits) of the reagent used.

In the mouth, mucin film is readily removed by harmless abrasives, is curdled by weak organic acids so that it may be more easily detached, or is dissolved by dilute alkalies or salts of alkali metals, these latter transforming it into alkaline mucinate. It is seen then, that the most efficient agent for the removal of film would be the action of the brush assisted by a weak alkali salt; that acids are not especially effective for this purpose; and, as previously stated, that the digestive ferments are ineffective.

Calcification of the Teeth by Dentifrices.—Recently introduced dentifrices composed largely of tri-calcium phosphate or of pulverized tooth enamel are claimed to have a solidifying or calcifying effect on the teeth. Their sponsers claim that through their action tri-calcium phosphate, which is the chief inorganic constituent of enamel, is dialyzed into the tooth structure and deposited there, thus increasing its hardness and reducing its permeability, with the result that the resistive power of the tooth is increased and partial or complete immunity to caries is produced. The theory of their chemical action is based on a correlation of the research work of Michaels, Rickert, Joseph Head, Pickerill, Bunting, Marshall, Price, Howe and others, on the calcium metabolism of the blood, saliva, and the body as a whole.

The possibility of producing increased calcification of tooth enamel in the mouth through the action of a dentifrice will have to be based largely on a correlation of these findings. After a serious study of this question, I am convinced, that it is possible to produce a certain deposition of calcium salt into porous enamel. However, owing to the fact that the attacking agencies concerned in caries production are acting at all times and that an artificial calcifying agent is acting for only a short period, the constructive force of the latter is not by any means sufficient to overcome the destructive agencies in the mouth. The work of McCollum, Mellanby, Howe, Gies, Price and others, indicates that the building of healthy bone and tooth structure as well as development and maintenance of the health of the other tissues of the body are to be accomplished mainly through dietary and general health measures and not primarily through the putting into the body fluids of pharmaceutical preparations of calcium, phosphorus, or other salts. After a serious study of dentifrices over a period of many years, I am led to the following conclusions, viz.:

Conclusions with Reference to Dentifrices. *First.*—The publicity material of the dentifrice manufacturers is producing an increased interest on the part of the public in oral hygiene but is also resulting, in many instances, in a misconception as to the functions of the dentifrice and its limitations as an agent in the treatment of oral pathological conditions.

Second.—The great majority of the public are not under the constant surveillance of the dentist and do not regularly practice efficient methods for maintaining the mouth in a sanitary and healthful condition. Owing to their pleasant taste, the temporarily refreshing sensation which they impart, and to convenience in handling, dentifrices will continue to be used by the masses, consequently, it is better not to discourage their use for the above types of individuals, but rather to guide them in the selection of those of harmless character.

Third.—For the above mentioned individuals, the dentifrice should be of simple formula, constructed with the principle idea of assisting the brush and dental floss in properly cleansing the hard and soft tissues of the mouth without injury.

Fourth.—Owing to variations in the conditions in different mouths, it is impossible to so construct a dentifrice that it will be suitable to the needs of all individuals. A dentifrice which may be harmless to one, may be entirely unsuited for use in the mouth of another.

Fifth.—The inclusion of proteolytic and amylolytic ferments in these preparations is unphysiologic and useless.

Sixth.—Grittiness and color have been largely eliminated from modern dentifrices, although there are still some which are harmful in these respects and which should be avoided.

Seventh.—The incorporation of strong antiseptics, astringents, and other highly medicated substances is not only useless, but may do great harm, especially in healthy mouths and to children. The chief function of a dentifrice is not to medicate but to assist the brush to cleanse harmlessly.

Eighth.—The chemical reaction of these preparations is not important since most of them increase the flow and alkalinity of saliva and assist in the removal of film. However, dentifrices of potential alkalinity in the presence of acids (such as milk of magnesia creams) may be of service in neutralizing acids of fermentation floating in the saliva. None of them especially increase the ptyalin content of the saliva as it flows from the salivary glands. Attempts to increase ptyalin content of mixed saliva are of very doubtful value.

Ninth.—Efforts directed toward the efficient building and maintenance of the hard and soft tissues of the oral cavity should include the following procedures.

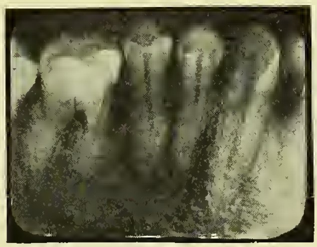


FIG. 217.—Generalized thickening of peridental membrane and lamina dura from trauma. Hypercentosis. Pocket formation between second bicuspid and first molar.

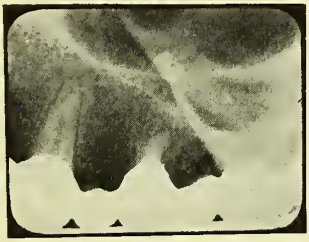


FIG. 218.—Marked thickening of pericementum and lamina dura indicating trauma. Granuloma, second bicuspid.

1. The usual hygienic measures recommended by the medical profession for the maintenance of health standards, including sunlight, exercise, fresh air, baths, and diet.

2. Inclusion in the dietary of acid fruits, green vegetables, whole wheat bread, milk, and other substances which naturally furnish the necessary vitamins, calcium, phosphorus and iron for the proper metabolism of the body.

3. The daily consumption of articles of food of a coarse, fibrous nature requiring heavy mastication, which will assist in cleansing the teeth and stimulating the gums and which will give the necessary roughage in the intestinal tract to stimulate peristalsis.

4. Practice of the proper methods for cleansing and maintaining the hard and soft tissues of the mouth in a healthy condition, including the proper use of the brush, dental floss and tongue scraper, and the use of

a harmless and *effective adjunct* in the form of a non-gritty, antacid, not highly medicated dentifrice.

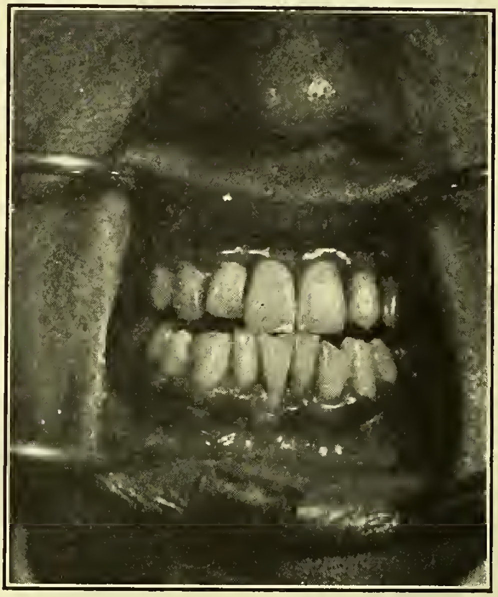


FIG. 219.—Recession of gingiva around the lower right central incisor due to traumatic occlusion.

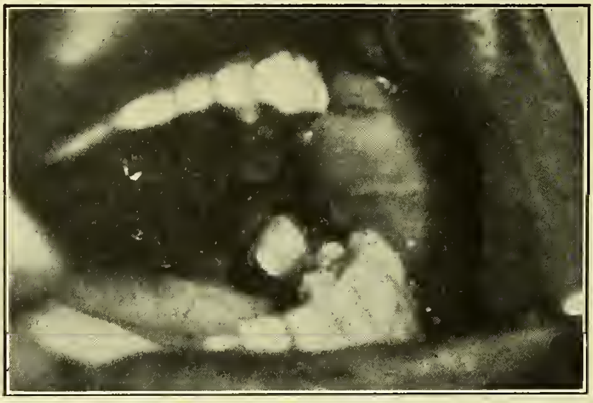


FIG. 220.—Distal drifting of lower third molar. The tooth has tipped and at the time the picture was taken the crown was below the root. Occlusal trauma.

Relief of Traumatic Occlusion.—By traumatic occlusion is meant undue stress on the teeth and their supporting structures or stress in excess of what they are normally subjected to ,or physically able to withstand. Stillman and McCall attribute 85% of cases of peridental disturbances to traumatic occlusion as a dominant factor (Figs. 217 and 218). This has been disputed by many authorities. Hugh W. MacMillan[2] claims that traumatic occlusion is in many instances not the contributing cause of periodontal disturbances, but that it is the *result* of the disturbance, due to loss of tone in the supporting structures or to drifting of the affected teeth.

Whatever the relationship of this condition to periclasia may be, it is accompanied by peridental injury and degeneration and consequently, its presence should be sought and the condition relieved. In such cases, it is found that when the teeth are brought together in centric or acentric occlusion, the affected teeth are subjected to excessive stress and are forced laterally in their sockets by the gliding of the inclined planes of opposing teeth, one upon the other. The condition may occur on any of the teeth of the denture, anterior or posterior, and results in the production of *occlusal trauma* which, if unrelieved, produces final loosening and loss of the affected teeth (Figs. 219 and 220).

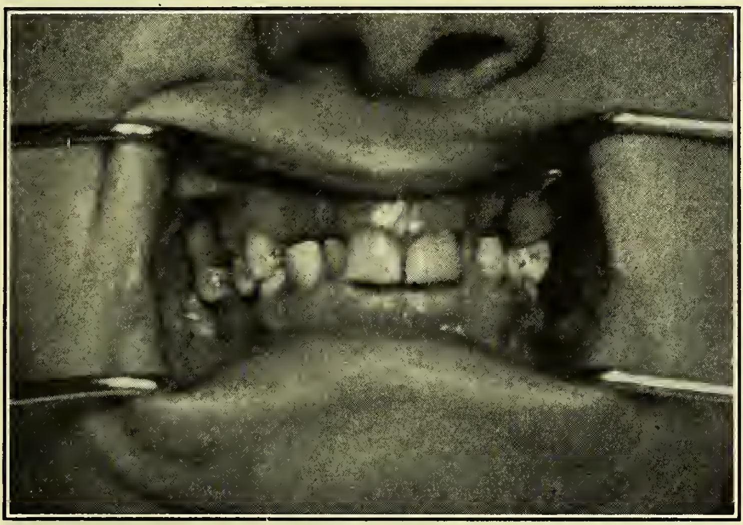


FIG. 221.—Excessive over-bite produced by non-replacement of missing teeth. Traumatic occlusion.

Early diagnosis is important, which is accomplished by placing the forefinger on the labial or buccal surface of the suspected tooth and instructing the patient to close the teeth in centric, protrusive and lateral occlusion. If in any of these positions, movement of the suspected teeth is felt by the finger, the presence of occlusal trauma is established and treatment is indicated. The use of carbon paper is also valuable for detecting the location and extent of traumatic occlusion. The condition may be due to irregularities of the teeth, high restorative dental operations (fillings, crowns, bridges), drifting of the teeth from their normal positions, loss of teeth, thus placing undue stress on those remaining, long over-bite, and high, closely interlocking cusps of posterior teeth,

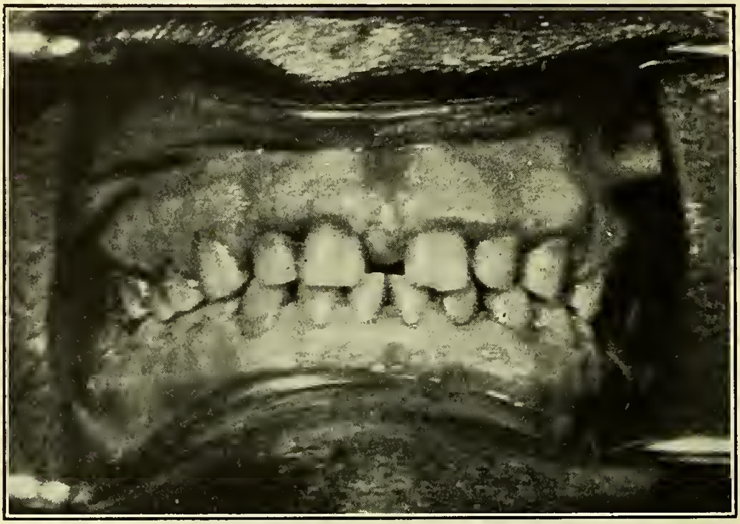


FIG. 222.—Teeth retained in a fairly good condition at the age of 74, due to the balanced functioning occlusion.

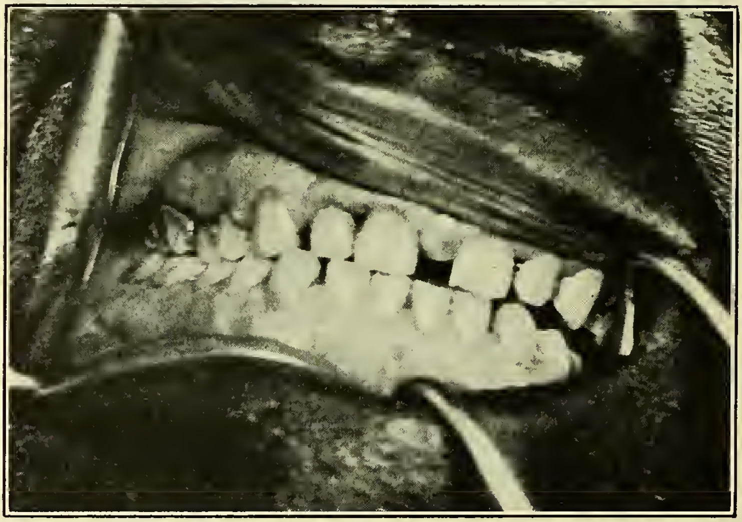


FIG. 223.—Same case as Fig. 222, showing the contact of several teeth in the right lateral excursion. Same conditions present on left side.

wedging on inclined planes of cusps during direct closure of the jaws and improperly fitted prosthetic appliances, producing lateral stress on the teeth to which they are attached (Figs. 221, 222 and 223). The cause should be sought and early relief instituted. In operative procedures involving restoration of tooth form, it is important that they be so shaped that undue stress be avoided. If operations of this type be found in the mouth, undue stress should be relieved, if possible, by grinding or other procedure, or the filling, crown, bridge or other appliance should be replaced by properly constructed substitutes. Many cases require reshaping of cusps or deepening of occlusal sulci by grinding and bringing the teeth into proper relationship. In some, where teeth are missing, it will be advisable to supply them by suitable restorations which will relieve stress on the affected teeth. In young patients, more rarely, orthodontic treatment is indicated.

Non-occlusion.—In cases of non-occlusion, periodontal disturbances are likely to arise from lack of function. In these cases it is important to establish proper function and occlusion through orthodontic treatment, restorative procedure, grinding adjoining teeth, biting exercises or resort to artificial massage through use of the tooth brush (Figs. 224 and 225).

Early Diagnosis and Filling of Cavities.—The detection and filling of all cavities in their incipiency is an important phase of prevention. Immediate filling of these cavities avoids pain, obviates the necessity for extensive cutting and consequent loss and destruction of tooth structure with possible pulp complications. Attention was called in the chapters on Diagnosis to the value of bite-wing films in the diagnosis of small proximal cavities which might otherwise escape attention.

Prophylactic Odontotomy.—The term "odontotomy" is derived from the Greek *odous*, tooth and *tome*, incision, meaning literally incision or cutting into a tooth. The phrase "prophylactic odontotomy" means, literally, cutting a tooth as a prophylactic procedure or preventive measure. The operation was first designed and has been advocated over a period of many years by Doctor Thaddeus P. Hyatt. It has not received the recognition it deserves as a preventive measure owing to a misconception of the terms "pits" and "fissure" as applied to the anatomy of the teeth on which the operation is performed and also to a misunderstanding of the scope and character of the procedure. A *pit* is a small, sharp-pointed depression in the surface of a tooth caused by faulty development. Pits occur at the base of fossae and often where several developmental grooves join, as well as at the termination of some developmental grooves.

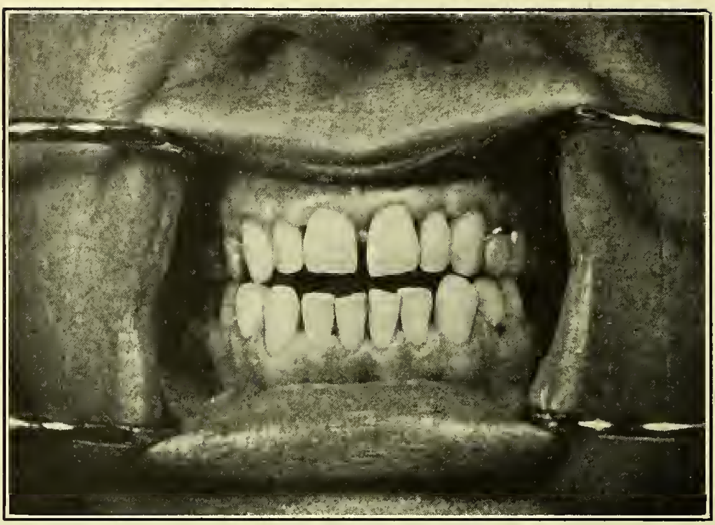


Fig. 224.—Congenital non-occlusion of anterior teeth. (Courtesy of Dr. Samuel C. Miller and The Journal of Dental Research.)

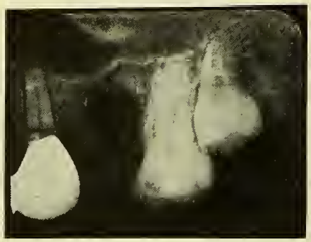


Fig. 225.—Recent extraction, upper first molar. Elongation of molar from lack of occlusion.

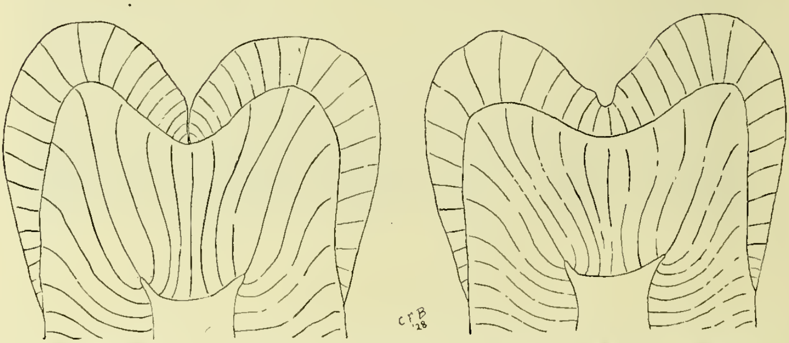


Fig. 226.—Diagram showing a deep pre-carious fissure penetrating to the dentin, and an open self-cleaning groove. (Courtesy of Dr. Charles F. Bödecker and the Publisher of Dental Items of Interest.)

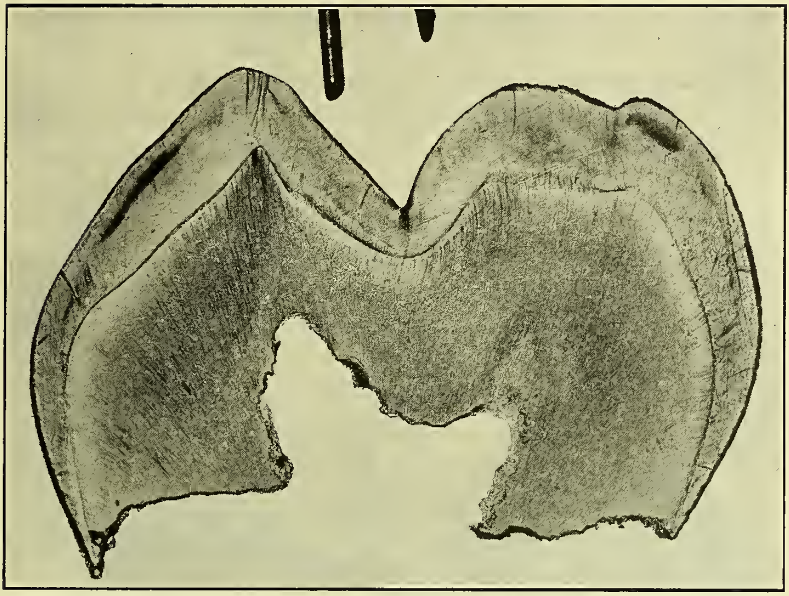


FIG. 227.—Open occlusal groove readily cleansed by toothbrush bristles seen above. (Courtesy of Dr. Charles F. Bödecker and the Publisher of Dental Items of Interest.)

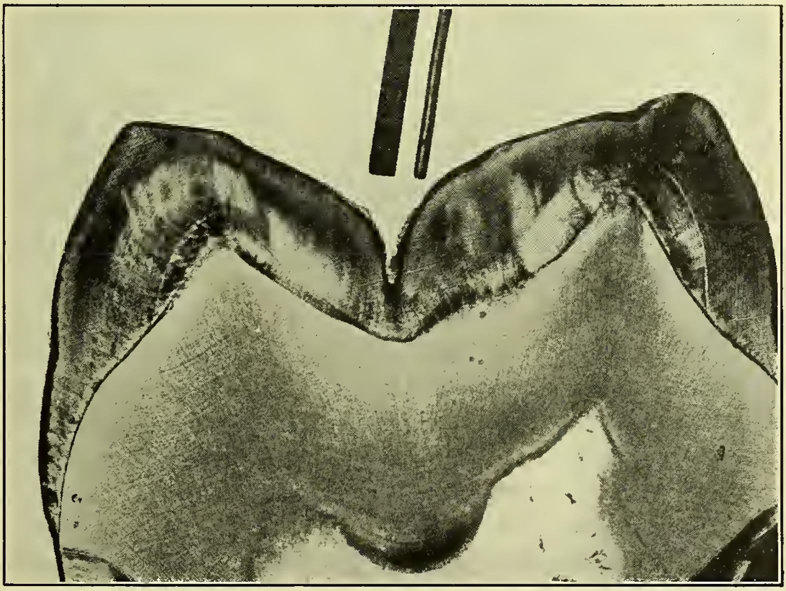


FIG. 228.—Deep occlusal groove very difficult to cleanse with tooth brush bristles seen above. (Courtesy of Dr. Charles F. Bödecker and the Publisher of Dental Items of Interest.)

They are found on the occlusal surfaces of molars and bicuspids, at the termination of the buccal grooves on lower molars, the disto-lingual grooves on upper molars and on the lingual surfaces of upper incisors. They should not be confused with fossae. A *fissure* is a small elongated fault in the surface of a tooth caused by imperfect coalescence of its lobes. Fissures occur in the bottom or floor and follow the lines of developmental grooves. They should not be confused with sulci or grooves (Fig. 226).

Pits and fissures are largely due to imperfect depositions of calcium and faulty union of enamel during the formative periods. They may be considered as defective tooth structure and are especially susceptible to decay. The fact that the majority of carious cavities in the mouth are found in these localities is due to this cause, fermenting food debris and micro-organisms finding an inviting field for localization. Since these areas are markedly susceptible to decay and caries occurs here at some time in the majority of cases, the early opening and immediate filling of defective pre-carious pits and fissures is a rational preventive measure and should receive careful consideration (Figs. 227, 228 and 229).

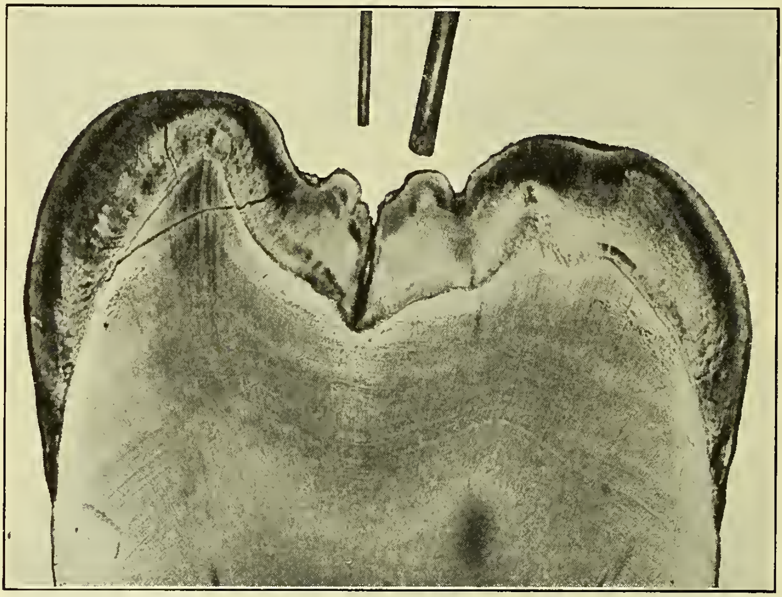


FIG. 229.—Pre-carious fissure impossible to cleanse with toothbrush bristles seen above. (Courtesy of Dr. Charles F. Bödecker and the Publisher of Dental Items of Interest.)

The operation of prophylactic odontotomy consists in the detection by means of the finest sharp pointed explorers of all defective pits and fissures, their opening and immediate filling or immunization whether decayed or not. The ideal time for performance of the operation is in early childhood soon after eruption of the teeth, but the procedure should be resorted to in all cases and at any time, with the possible exception of individuals who have passed the middle periods of life with complete immunity to caries. Even in these cases, there can be no assurance that a period of susceptibility may not arise from systemic causes, placing the teeth in a changed environment.

Diagnosis.—Because of the importance of the earliest possible detection of defective pits and fissures, the examination should be most thorough. The armamentarium should consist of suitable fine pointed explorers, 36 gauge, B. and S., mouth mirrors and a magnifying glass (either hand or binocular type). There should also be provided a means for drying and preserving dryness i.e. cotton rolls or napkins or both, compressed air and saliva ejector.

Pits and fissures can best be detected immediately following a careful and thorough prophylaxis. Unless the examination is made immediately following a prophylaxis, the teeth must be thoroughly brushed. Mouth napkins or cotton rolls, or both, are now placed around the teeth and the surfaces dried with absorbent cotton or spunk to be followed by compressed air. The surfaces should be gone over very carefully with a suitable explorer which should be selected as the one best suited to the particular tooth and surfaces to be examined. The magnifying glass will often disclose (even after careful cleansing) food packed into the fissures, for they may be so narrow as not to admit the finest tooth brush bristle. This food should at once be removed. A simple method for its removal is to alternately pass the point of the explorer along the fissure and to spray with considerable force a jet of water upon the dislodged debris. Should this method not be effective, pledgets of cotton saturated with alcohol and rubbed over the surface may prove helpful. Having cleared the area of debris, pass the explorer through the fissure and note if it catches, or if there is any discoloration indicating caries.

If the explorer catches, it may indicate a fissure, carious or non-carious or it may be a simple roughened surface which requires polishing to prevent future caries. A carious fissure may be so fine that even the fine pointed explorer will not detect its presence and it is here that the magnifying glass proves of value. These fissures may appear stained under the magnifying glass in contrast with the uninvolved surrounding structure or, when thoroughly dried may appear as a thin white line which, when carefully scruntinized shows clearly as disorganized tooth structure. The same careful examination should be made for the detection of pits.

It is necessary to examine the explorers from time to time during the examination, for even though we begin with sharp pointed instruments, they may become dull or broken and it is of the utmost importance that we maintain fine, sharp points at all times.

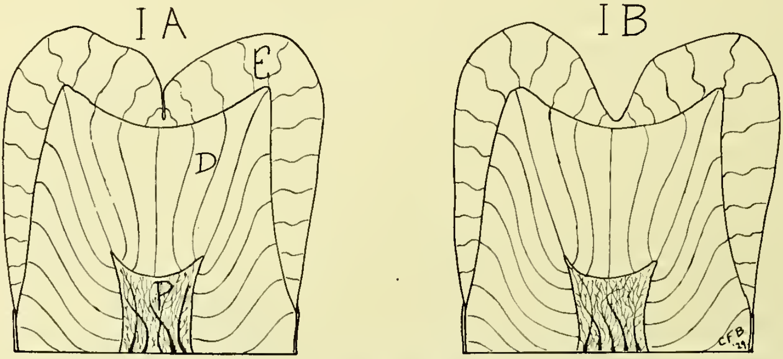


Fig. 230.—Diagram showing a pre-carious fissure which may be immunized (1A) and the result after early immunization (1B). (Courtesy of Dr. Charles F. Bödecker and the Publisher of Dental Items of Interest.)

Treatment.—In the majority of cases defective pits or fissures, whether decayed or not should be opened and filled after the technique described in the further discussion of prophylactic odontotomy in the chapters on Cavity Preparation and filling Materials. In a few cases, where there is no visible evidence of decay and where the pit of fissure apparently does not involve the entire thickness of enamel, immunization may be resorted to.

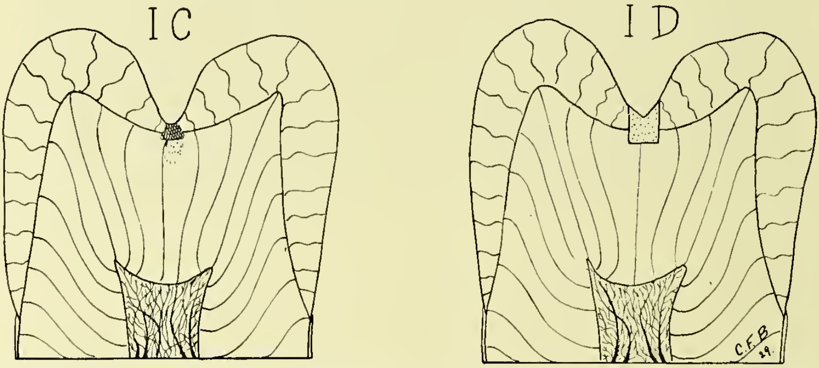


Fig. 231.—If caries occurs in later life from neglect, as seen in (1C), a small filling may readily be placed as seen in (1D). (Courtesy of Dr. Charles F. Bödecker and the Publisher of Dental Items of Interest.)

Immunization.—Immunization as practiced at the Forsyth Dental Infirmary is briefly described by Doctor Percy R. Howe in a personal communication to the Hyatt Study Club as follows:

"In these cases the pit or fissure is entered with a number ½ round bur. If this sinks through to dentin we cut out and fill. If a number ½ round bur does *not* sink through, the fissure is opened its entire length with first a number 1 round bur, followed by a number 2 bur, then a number 3 bur, but going no deeper. We cut out and fill about 80% of such cases however, leaving perhaps 15% for treatment by the above method and the balance (5%) for the silver deposit method of Doctor Howe, which latter method is employed for small or nervous children."

Prophylactic Odontoplasty.—By "odontoplasty" is meant those operations concerned with the filling of teeth. Prophylactic odontoplastic operations are operative procedures performed in such a manner as to assist in the prevention of disease of the teeth and periodontium.

Great care should be excercised during the performance of dental operations to avoid injury to the hard and soft tissues through the careless or too vigorous use of clamps, separators, polishing strips and disks, stones, ligatures, and similar appliances. Great damage may be done to enamel and dentin in the gingival region by clamps and separators. Wounding of the soft tissues by these agents or by ligatures, grinding and polishing materials, files, and matrix bands is a frequent cause of periodontal disturbance.

Fillings and inlays should be thoroughly finished to cavity margins and polished with no overhang to irritate the soft tissues or to afford lodgement for food. The same may be said with reference to crowns and bridges. Attention to restoration of proper proximal, labial and buccal contours and contact points is important to prevent impaction of food into interproximal spaces or against the gingiva on labial or buccal aspects with attendant injury to soft tissues, discomfort to the patient and subsequent periodontoclasia. Operations of this type when found in the mouth should be either corrected by proper shaping and polishing or be removed and replaced by proper restorations which will assist in maintaining as far as possible the proper inter-cuspal and occlusal relationship, form, contact and contour, and the integrity of the pulp, gingival tissues and pericementum.

Maintaining Constant Supervision.—To accomplish effective and lasting results in oral prophylaxis, patients should be seen regularly and at frequent intervals. The frequency of visits will be regulated largely by individual conditions. Some patients should be seen once a month, others every two or three months, while those with tissues of high resistive powers and who are enabled to and willingly give their mouths the intelligent and effective personal care required may be dismissed for longer intervals. At these visits, thorough examination and treatment should be instituted and the attention of the patient should be called to special localities indicating neglect or inefficient care of the mouth.

Preventive Dentistry of the Future.—A review of the preceding pages will bring to the reader a realization that the measures at present in use are largely mechanical, surgical or curative and that preventive dentistry in the present state of its development is only controlling disease. Regardless of our present progress, it must be admitted that the teeth are poorly calcified, many jaws do not develop to normal size and the investing and supporting tissues lack adequate resistance to bacterial invasion. True preventive measures for the future must aim to secure in so far as possible positive protection against oral disease in coming generations. These measures will have to begin on the child before birth, be emphasized in the early postnatal periods and sustained throughout the later periods of life. Hippocrates, the Father of Medicine, wrote in the fifth century B.C: "Diseases must be combatted in their origin." In the words of Woodrow Wilson "It is now time to do a lot of thinking."

Bibliography

1. McGehee, W. H. O.: A study of the tooth staining properties of various colored dentifrices, Dental Cosmos, March 1912, p. 289. Staining of teeth by colored dentifrices, Archiv fur Zahnheilkunde, July 1912.
2. MacMillan, Hugh W.: Clinical significance of disuse atrophy of alveolar process, Jour. Amer. Dent. Assoc., April 1927.

McGehee, W. H. O.: The present status of the dentifrice problem, Jour. Amer. Dent. Assoc., vol. 13, 1926, p. 1599–1609.

Stillman, Paul R. and McCall, J. O.: "Clinical Periodontia," MacMillan Co., New York.

Sorrin, Sidney and Miller, S. Chas.: "The Practice of Periodontia," MacMillan Co., New York.

Bödecker, Chas. F.: The tooth brush in relation to occlusal fissures, Dental Items of Interest, March 1927, p. 161.

Hyatt, Thaddeus P.: Conservation of non-carious first permanent molars, Jour. Amer. Dent. Assoc., May 1926.

Bödecker, Chas. F.: Difference in the penetration of dental caries on smooth and on grooved or pitted surfaces, Dental Items of Interest, Jan. 1928.

Hyatt, Thaddeus P.: Occlusal fissures, Brochure, Metropolitan Life Ins. Co., 1925.

Bunting, R. W.: Further studies of the relation of bacillus acidophilus to dental caries, Dental Cosmos, Oct. 1928.

Bödecker, Chas. F.: The eradication of enamel fissures, Dental Items of Interest, Nov. 1929.

Miller, S. Chas.: Non-occlusion as a factor in periodontal disease, Jour. Dental Research, vol. VIII, no. 5, Oct. 1928, p. 603.

Broderick, F. W.: Dental caries and pyorrhea, Dental Magazine and Oral Topics, June 1929 to April 1930.

Loeb, Jacques: "Proteins and the Theory of Colloidal Behavior," 2nd ed.

Fischer, Martin: "Oedema and Nephritis."

Stillman, Paul R. and McCall, J. O.: Acid dentifrice as an intelligence test, Dental Items of Interest, April 1923.

McClellan, J. B.: Influence of various stimuli on human saliva, Amer. Jour. Physiology, vol. 63, no. 1, Dec. 1922.

Michaels, Jos. P.: Sialo-semiology, Dental Cosmos, Dec. 1900.

Gies, Wm. J.: Studies of saliva and teeth, Jour. Nat. Dent. Assoc., 1914, p. 401.

Gies, Wm. J.: Further study of acid media, Jour. Allied Dental Societies, Dec. 1914, p. 554.

McGehee, W. H. O.: Relation of saliva to dental caries, New Jersey Dental Jour., July 1916, p. 257.

Kauffman, Joseph H.: A study of the tooth brush, Dental Cosmos, Feb. 1929.

Bödecker, Chas. F.: Patient's responsibility in maintaining a clean mouth, Dental Digest, vol. XXXIV, no. 9.

CHAPTER VII

INSTRUMENTS AND INSTRUMENTATION—CHAIR AND OPERATING POSITIONS—POSTURE

CUTTING INSTRUMENTS

Before beginning the performance of the various operative procedures with which the student will become familiar, it is first necessary that he possess some knowledge of his armamentarium. He must at once learn the names and uses of the various instruments with which these operations are performed as well as their proper care and manipulation. A description of cutting instruments is included here. Instruments for other purposes, such as those used for condensing and plugging gold and other materials, those needed for root-therapy, etc., and many others will gradually be mentioned and their uses described in their proper place.

"The workman is known by his tools." A visit to and inspection of the operating room of the dentist will at once reveal what manner of man he is. The care given his instruments and appliances, their orderly arrangement in the operating case, their sharpness, the regular lubrication of his engine and other mechanical appliances, is a definite expression of his character, the quality of service which he is daily rendering to his clientele, as well as an indication of the class of practice to which he is catering. The careless, inefficient operator will be revealed at once, and the high-class, capable, scientific, successful professional man will be recognized instantly, without inspecting any of his work. The same procedure may be followed in the examination of the student's operating case, with a like result.

It is important, then that the student at once begin to become acquainted with the various instruments and appliances which he is to use, and that he learn something about their manufacture, nature, care and uses before proceeding further. It is necessary that he early acquire habits of neatness in the care of his equipment, in its systematic arrangement, its thorough and regular cleansing and sterilization and in the methods of sharpening instruments. This chapter is devoted to that purpose.

BRIEF STUDY OF STEEL

Most dental instruments are manufactured from the hardest variety of steel. Steel is an alloy capable of being hardened, softened and tempered, made by the addition of a small percentage of carbon to iron. Its melting point is estimated by different authorities at from 1500–1600°C. There are two varieties of steel, viz. soft and hard. Soft steel contains 0.5% or less of carbon while hard steel contains from 0.5 to 1.5%.

Steel is *hardened* to its limit by heating to a full cherry red color and immediately plunging into cold water. In this state it is extremely brittle. The more carbon it contains, the harder and more brittle it becomes.

By *tempering* steel is meant the process of making it tougher and less brittle. This is accomplished by heating to a lower temperature than that used for hardening steel and then plunging in cold salt water, slightly acidulated water, oil, or mercury. Oil gives a tougher temper than water, while mercury gives an extreme degree of toughness. Hard steel is capable of much more temper than soft steel.

By *annealing* steel is meant the operation of reducing it to its extreme degree of softness. This is accomplished by heating to dull or "incipient" redness and cooling slowly. A greater degree of softness is produced by covering with sand, plaster or pumice, thus excluding the atmosphere, heating and allowing to cool while so covered.

A table showing the approximate temperatures with the corresponding colors produced during the heating of steel for the making of various dental instruments is herewith given.

TABLE

Temperature	Color	Use
423°F. to 450°F. (217° to 232°C.)	light yellow	enamel chisels, burnishers
469.4°F. (243°C.)	medium yellow	excavators, scalers.
496.4°F. (258°C.)	brown yellow	pluggers.
510.8°F. (266°C.)	brown purple	saws, shanks, of instruments.
534.2°F. to 570.2°F. (279° to 299°C.)	blue	spring temper

STAINLESS METALS

Owing to the tendency of steel to rust, experiments are being conducted with the idea of substituting certain of the stainless metals for use in the manufacture of dental and surgical instruments. Since these experiments are, at the present writing, in their infancy, little progress has as yet been made and little information is available as to the qualities and desirability of these metals for this purpose.

Stainless Steel.—This product is available in two principal varieties, viz.: (1) standard cutlery type and (2) high carbon type. Both are alloys of chromium, carbon and iron, the latter type being composed of chromium 15 to 23%, carbon 0.7 to 1.1%, the balance iron. It is extremely hard but requires very careful and precise heat treatment in manufacture. The resistance to staining of these alloys is attributed to the formation of a thin coating of transparent oxid on their surface, which must be kept highly polished at all times to prevent corrosion.

Monel metal is a natural alloy of nickel, copper and iron, containing approximately nickel 67%, copper 28% and iron 5%. It may readily be turned on a lathe and is markedly resistant to acids and super-heated steam.

Nichrome consists chiefly of nickel 60 to 80%, chromium 12 to 20% and iron 0 to 26%. It may be subjected to high degrees of temperature, does not oxidize easily, but does not readily maintain a sharp edge.

Stellite.—This product is available in several grades and consists chiefly of cobalt 65 to 90%, chromium 10 to 35%, with small quantities of tungsten, molybdenum, iron or nickel. Its chief characteristics are its high resistance to the action of acids, its hardness, strength, maintenance of cutting edge, density, and high melting point.

According to Max Pleasure[1] it is highly probable that in the near future alloys of the stainless type will be developed to the point where we shall see the passing of most of the cheaper and relatively impermanent steel alloys for use in the manufacture of instruments for dental and surgical purposes.

Tarno and Imperialite are now familiar examples of the use of stainless metals in dentistry.

STUDY OF INSTRUMENTS

Most instruments consist of three parts, viz.: *first*, the handle or shaft; *second*, the shank; and *third*, the blade or nib. The handle or shaft is that part which is grasped by the hand in using. The blade is the cutting part of cutting instruments while the working part of a plugger is known as the nib. The shank is the part connecting the handle or shaft with the blade or nib. The rule in selecting handles is, the more delicate the work intended to be performed, the smaller the handle and vice versa. Handles, whenever possible, should be of steel on account of convenience in sterilizing. For better balancing the instrument and to carry the blade or working part into inaccessible localities, *angles* are placed in the shanks of instruments.

Instrument Angles.—Doctor G. V. Black classified instruments into: (*a*) mon-angle, (*b*) bin-angle, (*c*) triple-angle, and (*d*) quadrangle, depending on whether they have one, two, three, or four angles in the shank.

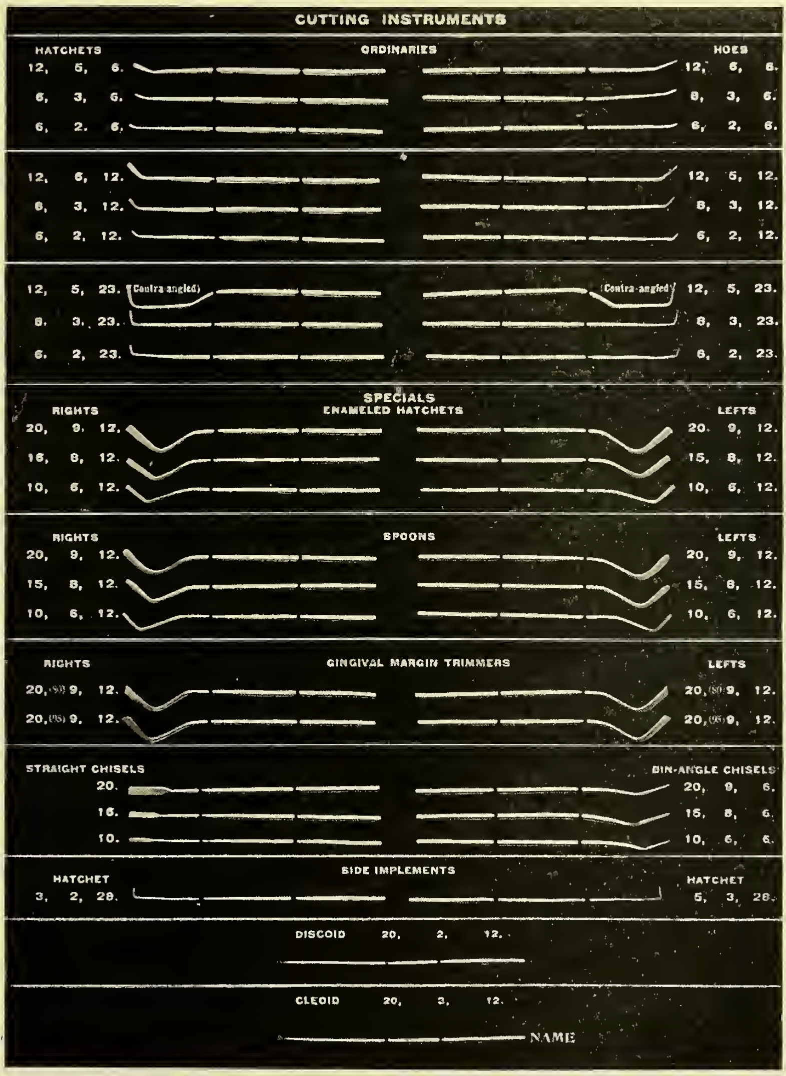


Fig. 232.—Set of cutting instruments made from brass wire, showing blades, shanks, angles and parts of shafts. (Courtesy of Dr. Fred W. Gethro.)

For better balancing and in order to bring the blade as near as possible in a direct line with the long axis of the shaft, the shanks of instruments are *contra-angled.* This variety of instrument has less tendency to turn in the hand when being used and consequently will do better work with less strain on the operator. Contra-angle instruments are divided into (*a*) bin-angle contra-angles; (*b*) triple-angle contra-angles; and (*c*) quadrangle contra-angles, depending on whether there are two, three or four bends or angles in the shank of the instrument. A well-balanced instrument should be so contra-angled as to bring its working point within two millimeters of the long axis of its shaft. Examples of instrument angles are seen in Fig. 232.

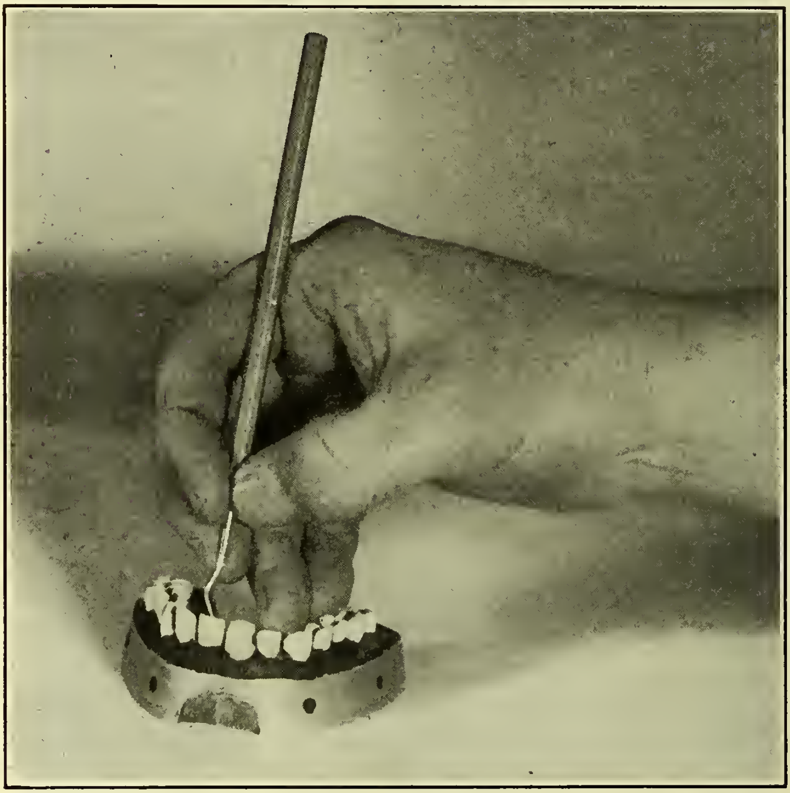


FIG. 233.—Pen grasp.

Instrument Grasps.—The student should, as soon as he begins to handle instruments learn the proper manner of grasping and holding them to their work. He should make a constant and close study of this until the proper grasps have become automatic. If he does not do this, he is likely to acquire bad habits in this regard which may cling throughout his career, lowering his efficiency and placing unnecessary strain on his capacity for constant productiveness.

Four fundamental Instrument Grasps may be described, viz.:

A. Pen grasp. Fig. 233.
B. Inverted pen grasp. Fig. 234.
C. Palm and thumb grasp. Fig. 235.
D. Palm thrust grasp.

The *pen grasp* is most frequently used and is the one indicated when great delicacy of touch is desired. The ideal form for this grasp is that in which the instrument is held, as the name indicates, similar to that used in holding a pen in writing, except that the shank should be in direct contact with the pulps of the thumb and first and second fingers. With practice, this gives great power, facility, delicacy and range of movement. This grasp will, however, have to be modified somewhat in different operating positions and localities in the mouth. With certain instruments and in different localities, the shank will have to be shifted more or less to the radial side of the cushion of the second finger. The second

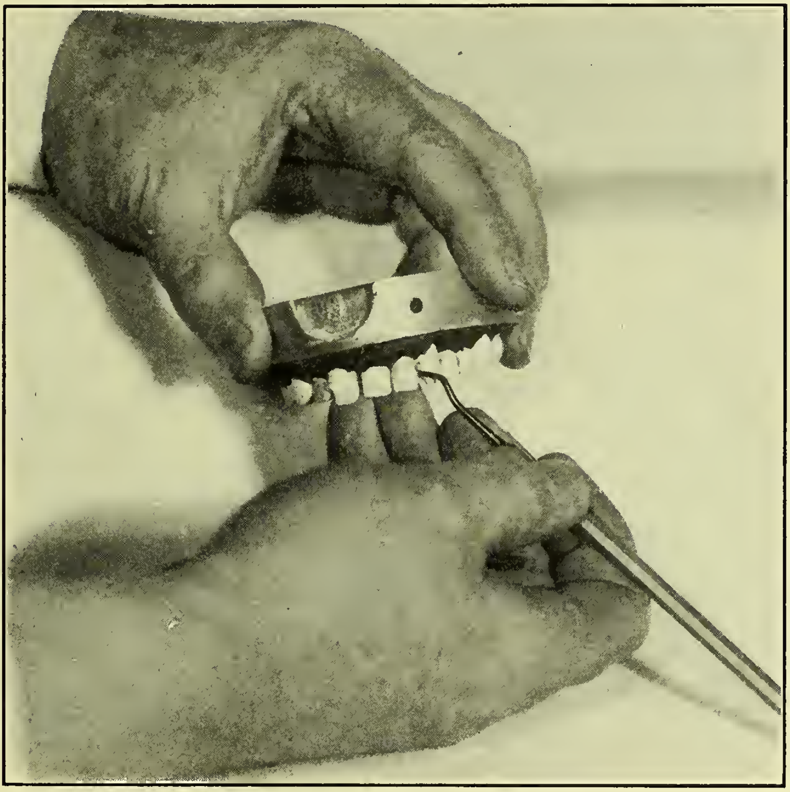


Fig. 234.—Inverted pen grasp.

finger, however, should not be allowed to crawl far under the shank toward the finger-joint as seen with some operators, thus limiting the range of movement and lessening the power of the thrust. Fig. 236.

The *inverted pen grasp* is similar to the pen grasp except that the position of the instrument is reversed so that the working part points toward instead of away from the operator. This grasp is used only occasionally and is also modified depending on position and direction of approach. Fig. 234.

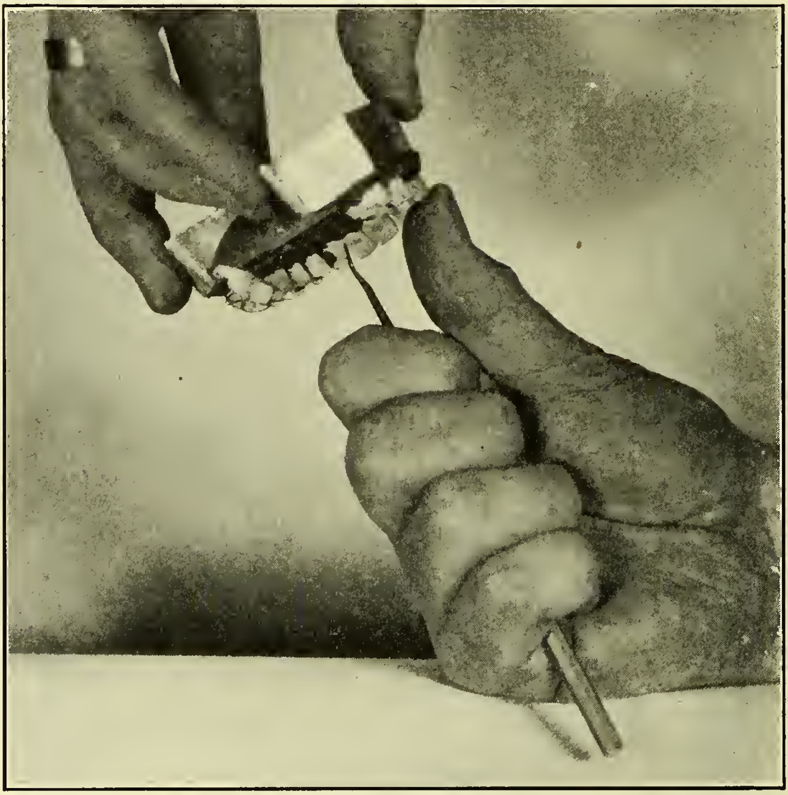


Fig. 235.—Palm and thumb grasp.

The *palm and thumb grasp* is the grasp of power and is accomplished by placing the instrument in a position similar to the one utilized in whittling a piece of wood, the handle resting in the palm of the hand and being grasped by the four fingers while the thumb rests on some adjoining surface. Fig. 235.

The *palm thrust grasp* is no longer used in Operative Dentistry. The end of the large handle is grasped in the center of the palm, the shank being held between the balls of the thumb and first and second fingers. No rest is utilized. A powerful thrust is thus obtained such as was formerly needed in plugging non-cohesive foil and operations requiring great power. It is still useful in other specialties.

Other grasps are used by Periodontists, Exodontists and other specialists, which do not concern us here.

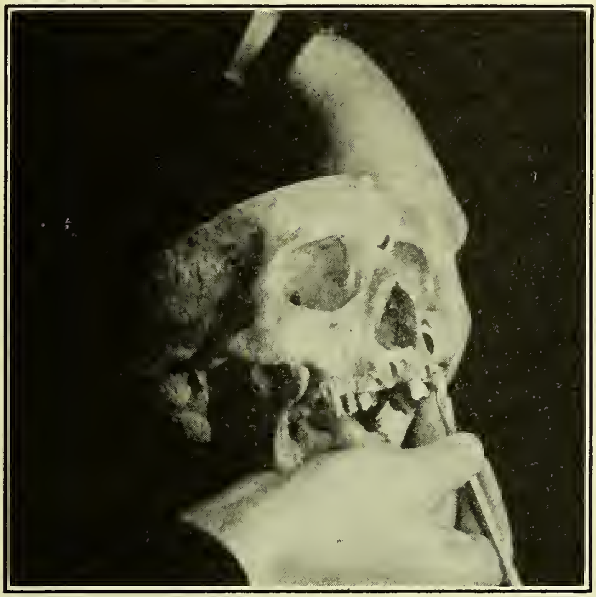


FIG. 236.—Modified pen grasp, showing rest on second finger. (Courtesy of Dr. Finn J. Bronner.)

Doctor G. V. Black designed an instrument known as the *manudynamometer* to test the finger-power or strength of the thrust. It consists of a "block" which, when pressed upon, automatically produces the movement of a pencil on a scale registering pounds. The person whose finger-power is to be tested grasps an instrument with the pen grasp and placing its blade or nib in contact with the "block" exerts all the force of which he is capable. The strength of his thrust is indicated in pounds on the register or "scale plate" by the movements of the pencil. In a large number of cases examined, it has been found that the average strength of thrust among dentists, as registered on this machine, is fifteen pounds—the minimum being five and the maximum thirty-five pounds. There has been gradual diminution of finger power among dentists since the introduction of the dental engine and cohesive gold. Correct instrument grasps and intelligent and persistent efforts directed toward increasing finger power and delicacy of touch tend to increase the efficiency and manipulative ability of the operator, thus perfecting his technic. Fig. 237 illustrates a manudynamometer designed by Dr. Finn J. Bronner.

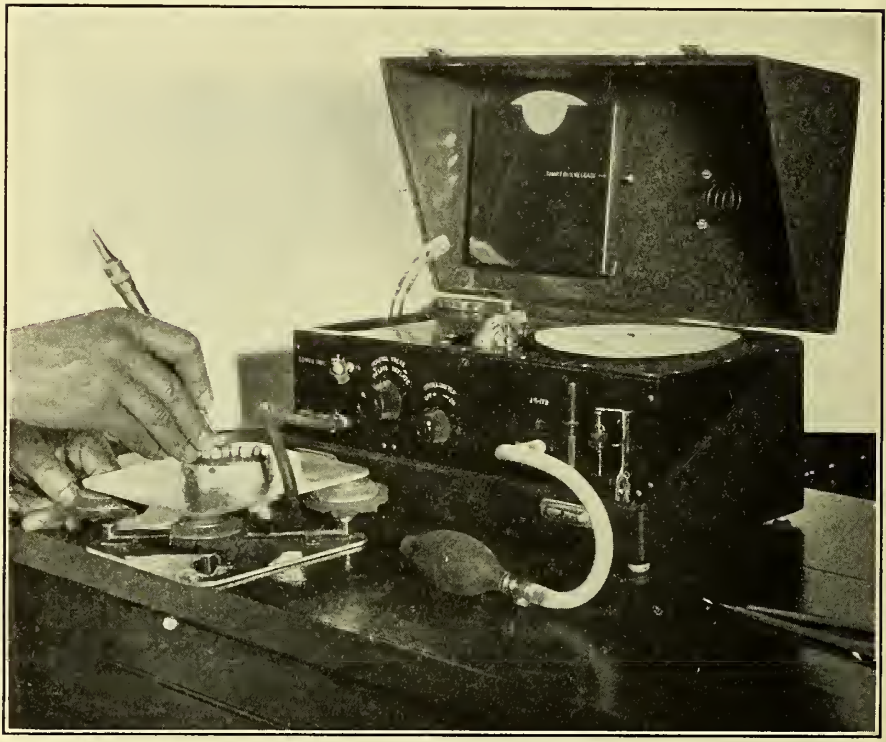


Fig. 237.—Manudynamometer.

Rests and Guards.—While maintaining the proper instrument grasp, it becomes necessary to steady the right hand during the performance of the operation, in order that the instrument may be held securely to its work without slipping. In the case of the pen and inverted pen grasps, this is usually accomplished by resting the third, fourth, or both fingers on the tooth operated upon or on some adjoining tooth or surface. The steadying of the hand is accomplished when the palm and thumb grasp is assumed, by means of the thumb, resting it on some adjacent structure. This position of the fingers or the thumb is known as *the rest*. The rest should be secured in so far as possible on an adjacent tooth in the jaw operated upon. Rests obtained on soft tissues or on the opposite jaw are unreliable and reduce the control of the operator on the instrument used. In many instances, the instrument also may be steadied and better held to its work by placing the fore-finger of the left hand in contact with its shank. In some cases "free-hand" operating will be necessary or advisable, dispensing with the rest and manipulating the instrument as in free hand drawing. In this method, control over the instrument is lessened and great care must be observed to prevent its slipping from its work. *The guard* is the position assumed by the thumb and fingers of the left hand to steady the parts operated upon and protect them from injury in case of accidental slipping of the instrument. The thumb frequently is placed on one side of the tooth operated upon and the fingers on the other, their position being frequently reversed depending on the location of the operation. In many instances, the shank of the instrument may be steadied with the left fore-finger while maintaining the guard. The accompanying illustrations of finger and operating positions should be closely studied and practiced. Fig. 238.

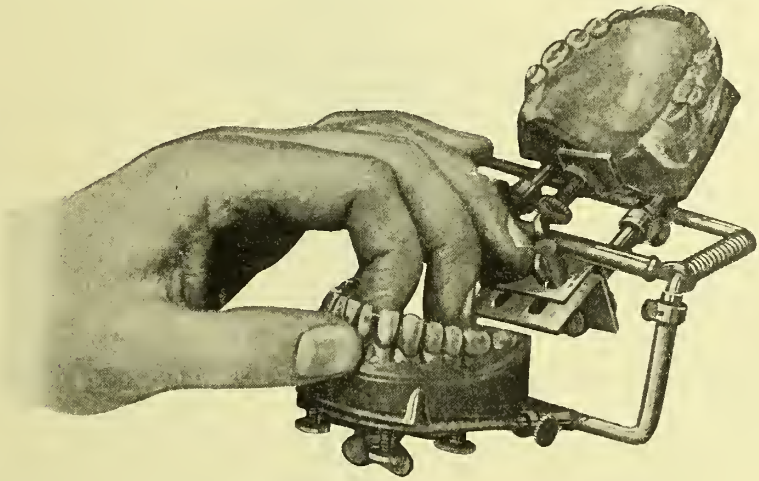


FIG. 238.—The guard.

Instrument Formulas.—Herewith is presented a Table showing the comparative measurements of length in the French Decimal or Metric and in the old or ordinary systems. These denominations, so far as their uses in dentistry require, are as follows:

One Meter—39 inches (approximate).

One Decimeter (one-tenth of a meter—4 inches (approximate).

One Centimeter (one-hundredth meter)—2/5 inches (approximate).

One Millimeter (one-thousandth meter)—1/25 inch (approximate).

Tenths, hundredths and thousandths of a millimeter.

One thousandth of a millimeter is known as a micron and is used only in microscopic work.

The Centigrade Circle is a circle (Fig. 239), divided into one hundred parts or degrees instead of 360° as is the astronomical circle. To convert centigrades, the degrees represented in this circle, into astronomical degrees, multiply 360 by the number of centigrades and divide by 100; or (a simpler method) after multiplying, cut off two figures (move the decimal point two figures to the left) as in calculating interest. A table is herewith presented Comparing Centigrade Angles with Astronomical Degrees:

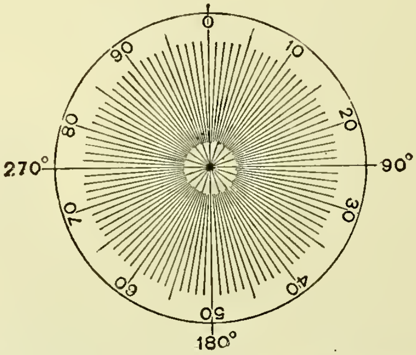


Fig. 239.—The centigrade circle. 25, 50 and 75 centigrades equal respectively 90, 180 and 270 astronomical degrees.

6 centigrades	21.6 degrees
12 centigrades	43.2 degrees
18 centigrades	64.8 degrees
23 centigrades	82.8 degrees
28 centigrades	100.8 degrees
80 centigrades	288.0 degrees
95 centigrades	340.0 degrees

Modern operating instruments are made to a definite scale and these measurements are placed on the shafts of the instruments, the first figure representing the width of the blade in tenths of a millimeter, the second representing its length in millimeters, and the third, the angle of the blade with the shaft in centigrades. In cases, however, where a fourth measurement is given, it represents the angle of the edge of the blade with the long axis of the shaft, and is placed second in the formula, the entire set of measurements being known as the "*formula name*" of the instrument.

The Boley Millimeter Gauge (Fig. 240) is sufficient for measuring all but the angles in the blade and shank of an instrument and these latter may be obtained on the centigrade circle. The smaller gradations on the main gauge are millimeters. The Boley gauge is valuable for measuring instrument blades, plugger points, drills, burs, differences in the measurement of teeth of the same denomination in the mouth, in comparing measurements, in restoring angles of teeth in gold-building operations, in selecting artificial teeth, and many other cases arising in dental practice.

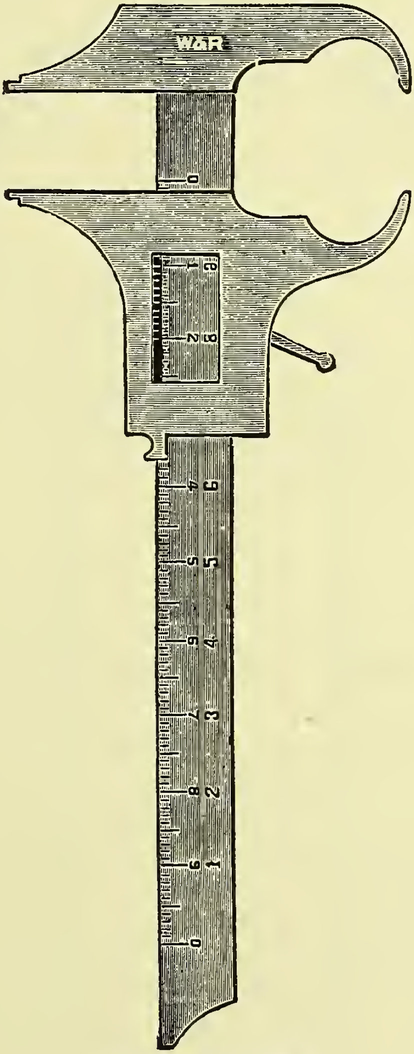


Fig. 240.—Boley gauge.

For measuring in tenths of a millimeter with this instrument a small scale known as the *Vernier*, located on the sliding piece by which the

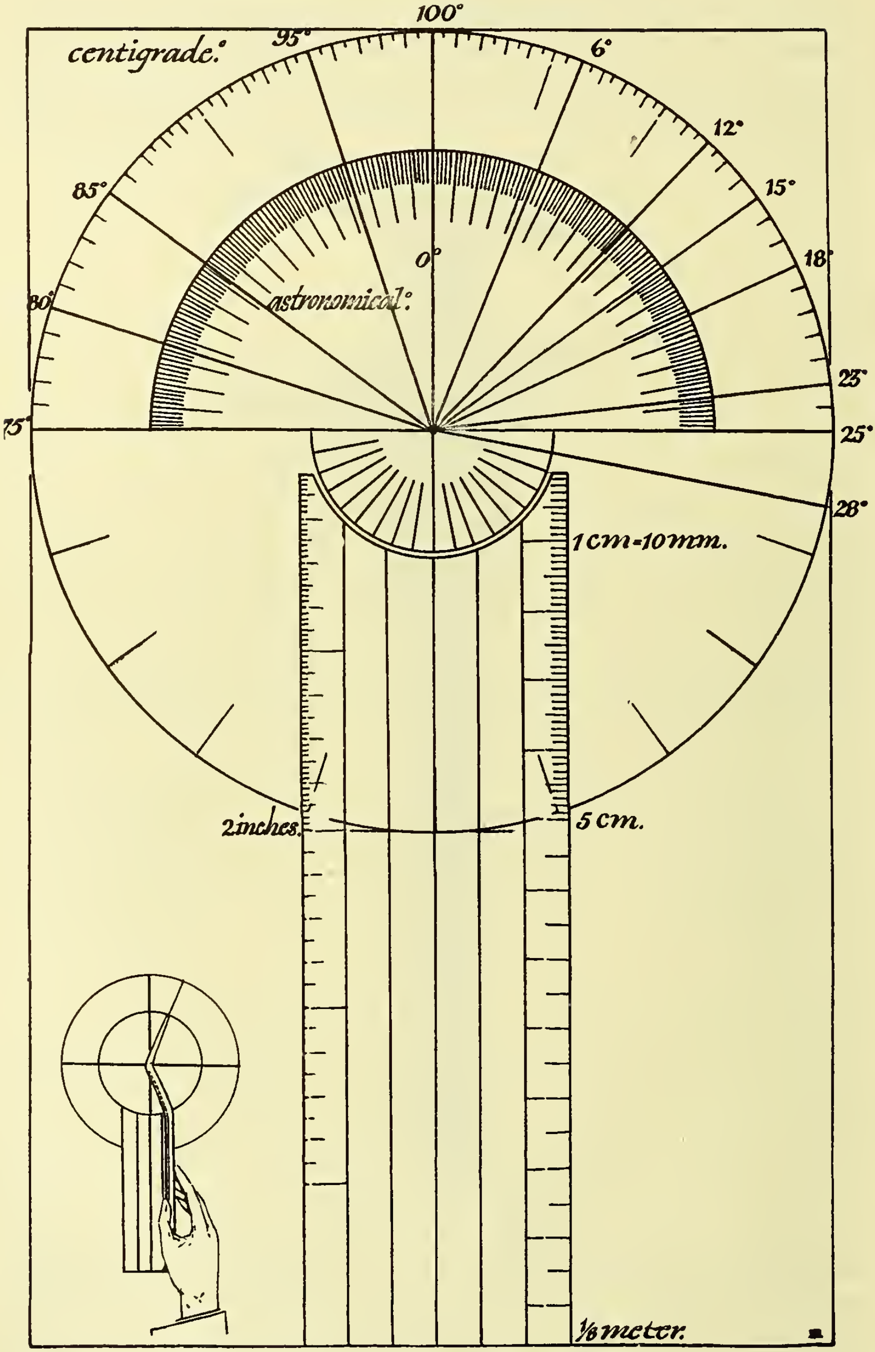


FIG. 241.—Illustration showing metric linear measurements in comparison with the ordinary scale and centigrade measurements compared with astronomical degrees. In the lower left hand corner is illustrated the method of determining angulation in the shanks of instruments on this scale. (Drawn by Doctor Victor Lane.)

jaws of the instrument are opened, is used. On examination, it will be seen that the divisions of this short scale (the Vernier) equal nine divisions on the main scale. When the zero divisions on the main scale and the Vernier are together, the instrument is at rest and is not capable of registering a measurement. Now, move the first division on the Vernier in contact with the first division on the main scale and the instrument will register 0.1 millimeter; move the second divisions together and 0.2 millimeters are registered; the third divisions giving 0.3 millimeter, the fourth divisions giving 0.4, the fifth divisions giving 0.5, and thus continuing until one or more millimeters are registered.

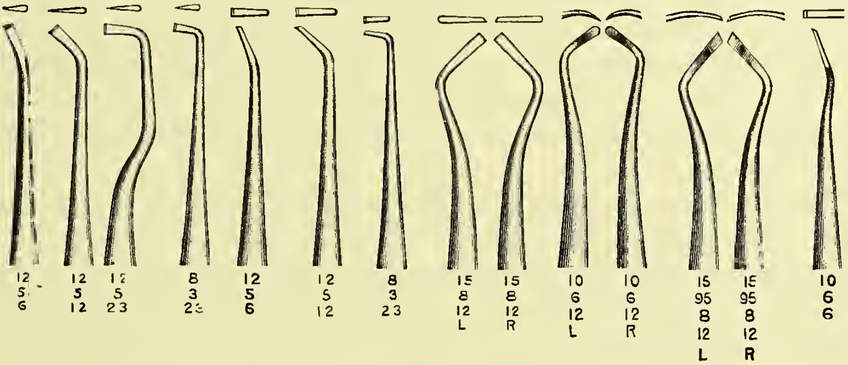


FIG. 242.—Cutting instruments. Hatchet, hoe and spoon excavators, enamel hatchets, gingival margin trimmers, and a bin-angle chisel. Formula names are shown.

Linear and centigrade measurements of instruments may be made on the scale illustrated in Fig. 241.

Long-handles and Cone-sockets.—Instruments are known as long-handled instruments if the handle, shank and blade are all made from one piece of steel. If the shank and blade or nib are separate from the handle and intended to be screwed into it, the instrument is known as a cone-socket instrument. The advantage in the cone-socket instrument is that, if the working part is broken, it may be replaced at less expense; the disadvantage is its tendency to loosen at the joint. Care should be excercised to see that cone-socket instruments are tight in the handle before using. See Fig. 249.

The blades of some cutting instruments, such as chisels, are beveled on one side only, while others, such as hatchet excavators, are *bi-beveled;* that is, beveled on both sides. Instruments are frequently made in pairs, the angles in the shank throwing the working point of one to the right and the other to the left, both instruments being intended to do the same character of work on opposite sides of a cavity or of the mouth.

These are known as *rights* and *lefts*. Familiar examples are spoon excavators and various hand-pluggers. Fig. 242.

CLASSIFICATION ACCORDING TO NAME

Instruments are classified according to name into:

First.—Order names.
Second.—Sub-order names.
Third.—Class names.
Fourth.—Sub-class names.

Order names. These names denote the purpose for which the instrument is intended, as excavator, plugger, chisel, drill, mallet.

Sub-order names. These define the manner or position of use of the instrument, as automatic mallet, hand plugger, pull scaler, bicuspid clamp.

Class names. These describe the working point of the instrument, as hatchet excavator, spoon excavator, round bur, inverted cone bur, serrated plugger.

Sub-class names indicate the shape of the shank, as mon-angle, bin-angle, triple-angle, contra-angle.

These names frequently are combined in the description of instruments, as mon-angle hatchet excavator, gingival margin trimmer, triple-angle contra-angle spoon excavator, etc.

The student has now become familiar with some of the properties of steel, the substance from which most dental instruments are made, has obtained some preliminary knowledge of instrument nomenclature, various instrument grasps, the use of rests and guards, as well as of the general principles of instrument construction. We are now concerned with instrument classification, a brief description of their individual characteristics and the uses for which they are intended.

CLASSIFICATION ACCORDING TO USE

Dental instruments may be classified according to use into (*a*), cutting instruments, (*b*) condensing instruments, and (*c*) miscellaneous instruments.

CUTTING INSTRUMENTS

Cutting instruments are those designed for the cutting of the hard and soft tissues of the mouth, removal of deposits from the teeth, and for finishing fillings. They may be mentioned by name as follows:

Excavator
Chisel
Bur
Drill
Reamer
Lancet
Scaler
File
Saw
Knife
Wheel
Point
Disc
Strip

An **Excavator** is an instrument for the excavation and removal of decay and the shaping of the internal parts of cavities. There are five forms, viz., the hatchet, the hoe, the spoon, the discoid, and the cleoid. Their names indicate their form, they being designed after the ordinary hatchet, hoe, spoon, etc. See Fig. 242.

The hatchet excavator has the edge of the blade running in a direction parallel with the handle and is bi-beveled. In the hoe excavator the edge of the blade is beveled on the side distal (away from) to the shaft and runs at right angles to it. The hatchet and hoe are used for the removal of the harder varieties of decay and to give form to the internal parts of cavities. The spoons and discoids (round spoons) are intended especially for the scooping out of soft decay and are beveled only on the distal (far) side. Cleoid means claw-like, the instrument having a sharp point with two rounded edges running from it—really a spoon excavator with the blades running to a sharp point. It is especially designed for deepening the angles of pulp chambers at the canal entrances during removal of the pulp. Also it may be used for carving grooves and fissures in filling and inlay work.

A **Chisel** is an instrument designed after the ordinary carpenter's tool, and intended for cutting enamel. It usually is beveled on one side only and the shank may be straight or bin-angled. Special forms of chisel are the enamel hatchet and the gingival margin trimmer. The *enamel hatchet* is a variety of chisel in which the blade (beveled on one side) is placed in hatchet form by contra-angling the shank. It is made in rights and lefts with the bevel on opposite sides for cutting enamel. The *gingival margin trimmer* is a variety of chisel especially designed for giving the proper bevel to gingival enamel margins; it is made in rights and lefts, two pairs of different size for bevelling mesial cavities and two pairs for distal cavities. See Fig. 242.

The **Bur** is a form of drill for use in the handpiece of the dental engine, intended for the rapid cutting of tooth structure during the opening and preparation of cavities. Burs may be divided into two groups, according to shape, and depending on whether they are intended to cut round or plane surfaces.

Group 1, for cutting concave surfaces, includes the round burs. Fig. 243.

Group 2, for cutting plane surfaces and angles, includes the inverted cone and fissure burs. Fig. 244.

Dentate or cross-cut burs are burs with the cutting blade divided into teeth, very rapid cutters, intending especially for attacking enamel. (Fig. 245.)

Plug-finishing burs are burs of a finer cut, of similar shape to those mentioned in Groups 1 and 2, and also oval, pear and bud shaped, intended for finishing and burnishing fillings. Fig. 246.

The **Drill** is an engine instrument used for boring or drilling holes in tooth structure (as in opening into a pulp chamber from the surface, where no cavity exists), or in bone (as during the treatment of an alveolar abscess). A drill also is valuable for following out fissures and for removal of old fillings. The spear-point, square and twist drills are familiar forms. A special form, known as a diamond drill, is valuable for drilling cavities in artificial teeth. Fig. 247. Drills may be readily made from old fissure and inverted-cone burs, by bevelling them on opposite sides on a stone. A bi-beveled dentate fissure bur, made from an old dentate bur, is valuable for drilling through enamel and dentin.

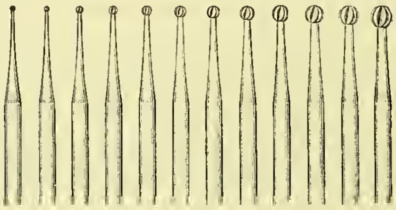


FIG. 243.—Round burs.

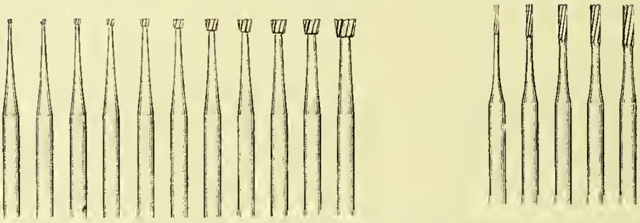


FIG. 244.—Inverted cone and plain fissure burs.

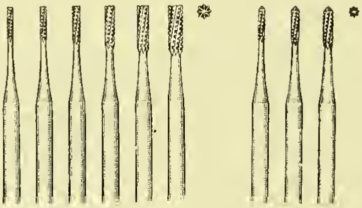


FIG. 245.—Flat and pointed end dentate fissure burs.

A **Reamer** is a hand or engine instrument for enlarging root canals during treatment. Drills never should be used for this purpose on account of the danger of perforation of the side of the root. A flexible reamer, which will follow the route of the canal and enlarge it, is occasionally indicated. The tapered canal reamers (spiral form), are valuable for enlarging the entrance to canals. Fig. 248.

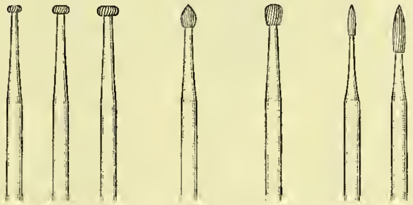


FIG. 246.—Plug finishing burs.

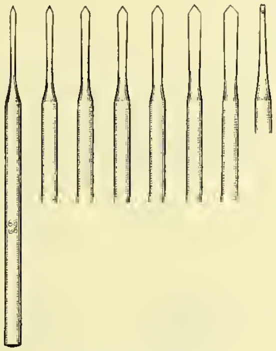


FIG. 247.—Spear point drills.

A **Lancet** (Synonyms, Scalpel, Bistoury) is an instrument of knife form, designed for cutting the soft tissues. The term lancet is applied more frequently to that form of knife for use about the mouth as in the lancing of abscesses and in all minor oral surgery operations. Fig. 249

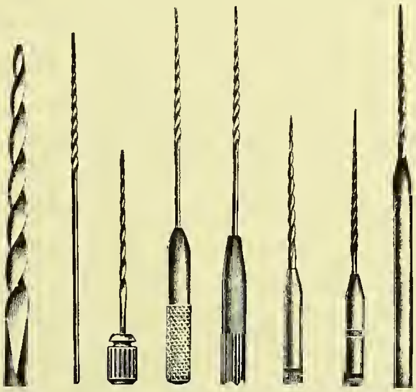


FIG. 248.—Pulp canal reamers. The one to the left is much enlarged.

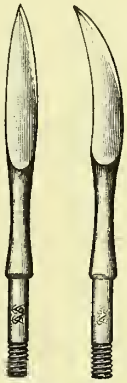


FIG. 249.—Lancets for cone socket handles.

A **Scaler** is an instrument for the removal of calculus from the teeth. The blade is often similar to the hoe and hatchet excavators. The instrument has various angles in the shank and is used mostly with a pull cut, though some are used with a push cut. Scalers are made in rights and lefts, in many different sizes and shapes, some for the removal of large deposits on the crowns of teeth and others for minute particles at and under the gingival margin.

A **File** is an instrument designed for filing down or removing surplus filling material. Fig. 250.

The **Saw** generally is used in a special frame and has teeth on one or both sides. It is used for separating teeth and for trimming surplus material from proximal fillings.

The **Knife** is an instrument with a thin knife-like blade, made in various shapes, designed for trimming or shaving off surplus filling materials at the gingival, buccal and lingual margins of proximal fillings. Fig. 250.

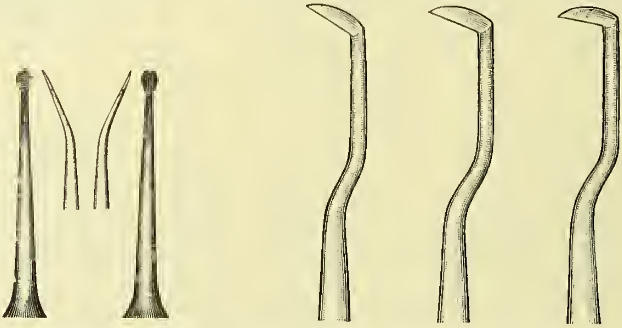


Fig. 250.—Rhein files (approximal trimmers) and Black finishing knives.

Wheel.—A small grindstone, ranging from one-half inch to one inch in diameter, of various thicknesses, and made usually of corundum or carborundum, of which the latter is harder, cuts more rapidly and lasts longer. Fig. 251.

Point, Disc.—Made of the same materials, the *point* being of various shapes, as barrel, cone, bud, bell, etc., and ranging in several sizes. Points are also made of Arkansas, Scotch, and Hindoostan stone, when intended for finer grinding, these materials being of a much smoother grain than carborundum. The "Gem" point is excellent for finer grinding. Fig. 252. *Discs* are made of paper and cloth, charged with emery, sand, garnet and cuttle-fish bone, for polishing purposes. The cuttle-fish disc is the finest grain of these and is intended for very fine cutting and polishing. A variety of disc known as Crocus is very valuable for putting an extremely velvety finish to gold fillings. Discs for carrying polishing powders, such as pumice, corundum flour, chalk, oxid of tin, whiting and rouge are made of celluloid, felt, leather, moose-hide, soft rubber, chamois, etc., while points for the same purposes are made of wood, leather, felt, chamois and soft rubber. Special *mandrels* are made for mounting all of the above. See Fig. 251.

Cloth and paper *strips* of various widths and charged with the same materials as the discs, as well as with carborundum, flint and lava, are utilized for finishing and polishing fillings.

Condensing and miscellaneous forms of instruments are described in their proper place in subsequent chapters.

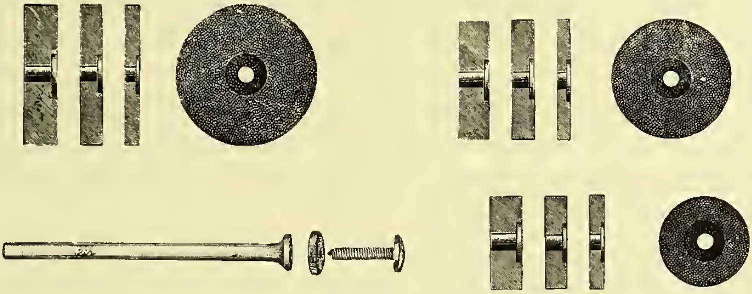


FIG. 251.—Carborundum wheels and a disk mandrel.

"The workman is known by his tools." A glance into the operating case of a student or dentist is sufficient to enable a good judge to gauge the capabilities and character of work being done by its owner.

SHARPENING INSTRUMENTS

Cutting instruments should be kept sharpened if ideal results in operating are desired. The possession of a good Arkansas or fine car-

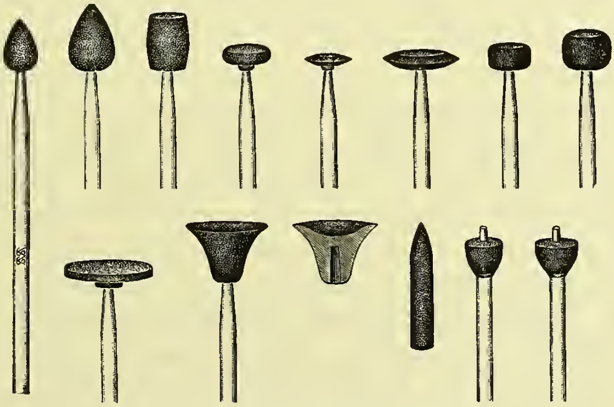


FIG. 252.—Carborundum points.

borundum stone is essential to the attainment of this object. The stone should not be less than five or six inches long and one and one-half to two inches wide. It should be kept constantly within easy reach, slightly moistened with a drop or two of lubricating oil. Avoid too much oil. The passage of an excavator or chisel over the stone with a few long, firm strokes will be sufficient, if resorted to at intervals, to keep the instrument sharp. Care should be taken to follow the original bevel of the blade and not to establish false bevels during the sharpening process. The stone should rest on a firm surface, should be kept clean and free from grit and scratches by the use of a clean napkin slightly moistened with oil. If the surface of the stone in time becomes marred, it may be refaced by rubbing it on a sheet of fine emery paper laid flat on a table or work bench.

No attempt should be made to sharpen burs, since it is impossible to accurately do so. When a bur becomes dull it should be discarded. Files should be sent to the manufacturers for resharpening since, when they become dull, they are of very little use.

The important point to observe in sharpening hand-cutting instruments is to avoid the grinding of rounded surfaces, but rather to form plane surfaces following the original bevel of the blade. This is accomplished by replacing the instrument in proper relationship with the stone and maintaining that relationship through the application of a rest during the excursions of the instrument over the stone. The rest may be obtained by contact with the stone of one or more fingers of the hand holding the instrument.

The *hatchets* should be ground on both sides, since they are bi-beveled and the edge should be left sharp and square with the blade, the angles, sharp and definite, not rounded. They should be ground with a stroke including the full length of the stone. A finger rest should be obtained which should slide with the stroke in order to maintain the proper angle of the blade to the stone throughout the stroke.

The *hoes* are ground on only one side, since they have a single bevel on the distal side of the blade. The position of the hoe on the stone will vary, depending on the centigrade angle of its shaft. It may be placed with the edge pointing to or away from the operator as may be found more convenient depending on whether it is a 6, 12 or 23 centigrade instrument. To avoid chatter of the blade against the stone, the greatest pressure should be applied in some instances during the push stroke, in others during the pull stroke. For each instrument used, the best relation to the stone should be studied and correct finger-rests should be adapted to produce accurate results.

The *chisels* are the easiest to grind and the short bevel present on one side of the blade should be maintained. They may be held with the pen grasp and sharpened with a pull stroke the full length of the stone or the inverted pen grasp may be used with a push stroke. In either method, a secure finger-rest should be obtained to steady the instrument.

The *spoons* and *discoids* are the most difficult to grind. They should be so placed on the stone that the motion in grinding will maintain the correct bevel throughout the procedure. They are sharpened with a pull stroke traveling over the full length of the stone. In the beginning, the instrument is placed at the far edge of the stone with its shaft pointing toward the operator. As the instrument is pulled toward the operator, the shaft is given a rotary movement away from the operator, becoming perpendicular in the middle of the stone and pointing away from him on the completion of the stroke, at the near end of the stone. These instruments may also be sharpened with an emery disk in the engine though not so correctly or efficiently as with the stone.

Sufficient has been said to guide the student in using proper methods of sharpening other types of instruments. Efficient work can not be done with dull instruments. Sharp instruments greatly reduce the pain of operating, shorten the time in operative procedure and produce correct results with much less effort. Instruments should not be sharpened at occasional intervals after they have become dull, but should be kept sharp, clean and sterilized at all times. Students who are unwilling to do this should be discouraged from continuing the study of dentistry, since they will make poor operators.

INSTRUMENT FORMS AND FORMULAE

To Doctor G. V. Black is due the credit for presenting to the profession the present scheme of nomenclature and classification of dental operating instruments. Previously, the lack of such a system was a great bar to progress and instruments were manufactured without any definite scientific principle of construction. As a result, they were improperly balanced and very crudely and imperfectly performed the work for which they were intended. The introduction of Black's system brought order out of chaos, greatly improved methods of instrumentation and gave teachers and students a nomenclature which could intelligently be used in discussing instruments and technical procedure.

Since Doctor Black's time, other men have introduced certain modifications of his original formulae. These modifications, however. have been based on the original work of Black to meet certain individual needs and preferences. As an example of this may be mentioned the

Woodbury-Crandall and the Woodbury sets of instruments which are largely modifications of Black's original formulae. There are many valuable instruments in these sets, some of which the author recommends. At the present time there is a tendency to modify many of the original formulae of Black to meet modern needs in operative procedure. Many modifications of these formulae will be seen throughout the text.

At the beginning of the course in Operative Technology, a close and thorough drill in the study of instrument forms and formulae is necessary in order that the student may become perfectly familiar with the character, uses, proportions and measurements of the various instruments used in Operative Dentistry. He should learn the formula names of all instruments, be able to readily distinguish them by these formulae and immediately begin to speak of them in these terms. This will lead to definiteness in selection for each technical procedure, increased skill in operating and development of manipulative ability.

In the Black system of instrument nomenclature, hand-cutting instruments are divided into (1) *Ordinaries*, including the hatchets and hoes, formed on definite ranges of formulas and (2) *Specials*, including those intended for special purposes, formed on separate ranges of formulas from the ordinaries, such as chisels, enamel hatchets, spoons, gingival margin trimmers and side instruments. The side instruments are the discoids, cleoids and hatchets of special design and formula, the latter being intended for shaping the incisal angles in proximal cavities in incisors and cuspids. The specials also include certain types with long blades for use in deep seated cavities. See Fig. 232.

Ordinaries.—The ordinaries present three measurements in their formula, the first indicating the width of blade in tenths of a millimeter, the second the length of blade in millimeters and the third the angles in the shank in centigrades. The hatchets and hoes follow a rather limited range of measurement which usually falls within those indicated in the tables as shown at the top of p. 227. Their formulae may be easily memorized. The first table brings those of equal angle together and the second groups those with the same sizes of blades. The repetitions in the lines of figures in these tables should be noted and the different sizes of hoes and hatchets should be selected, compared and arranged in order with the measurements in these tables until the student is familiar with them and is enabled to select from his set any instrument according to its formula name.

Specials.—The formulas of the specials are on a different set of sizes or the ranges are on different sizes from those of the ordinaries. They

Table 1 (Black's Operative Dentistry)

The blades are 12 wide, 5 long, 6 centigrades angle.
8 wide, 3 long, 6 centigrades angle.
6 wide, 2 long, 6 centigrades angle.
12 wide, 5 long, 12 centigrades angle.
8 wide, 3 long, 12 centigrades angle.
6 wide, 2 long, 12 centigrades angle.
12 wide, 5 long, 23 centigrades angle.
8 wide, 3 long, 23 centigrades angle.
6 wide, 2 long, 23 centigrades angle.

Table 2 (Black's Operative Dentistry)

The blades are 12 wide, 5 long, 6 centigrades angle.
12 wide, 5 long, 12 centigrades angle.
12 wide, 5 long, 23 centigrades angle.
8 wide, 3 long, 6 centigrades angle.
8 wide, 3 long, 12 centigrades angle.
8 wide, 3 long, 23 centigrades angle.
6 wide, 2 long, 6 centigrades angle.
6 wide, 2 long, 12 centigrades angle.
6 wide, 2 long, 23 centigrades angle.

include straight chisels with only one measurement, indicating the width of blade; bin-angle chisels with three measurements (width of blade, length of blade and angle in the shank); enamel hatchets and spoons in right and left, each with three formula measurements; gingival margin trimmers with four figures in their formulae; and the side instruments. In the side instruments, the hatchets and discoids present three measurements, while the cleoid has only one (width of blade). In the straight chisels, the range is designated as chisel 20, chisel 15 and chisel 10, three sizes. There are also three sizes of the bin-angle chisels, all being on a 6 centigrades angle, viz. bin-angle chisels 20-9-6, 15-8-6 and 10-6-6. The enamel hatchets, rights and lefts, are all on the same angle, 12 centigrades, in three different sizes, viz. 20-9-12, 15-8-12 and 10-6-12. The spoons, rights and lefts, present the same formula as the enamel hatchets, viz. 20-9-12, 15-8-12 and 10-6-12. The gingival margin trimmers, designed to automatically give the proper enamel bevel to gingival margins, present a fourth measurement, placed second in the formula, which indicates the angle of the blade with its shaft. This angle is 95 centigrades for those designed for distal cavities in bicuspids and molars and 80 centigrades for mesial cavities in the same teeth. Their formulas are, rights and lefts, 20 (95)-9-12 and 20 (80)-9-12 for molars and 15 (95)-8-12 and 15 (80)-8-12 for bicuspids, making eight instruments to the set. The range 10-6-12, as in the enamel hatchets and spoons is omitted.

Of the *side instruments*, the hatchets are in the ranges 5-3-28 and 3-2-28. The discoid presents the formula 20-2-12 and the cleoid 20.

The specials should be closely studied in the same way as the ordinaries, until the student is thoroughly familiar with them and is enabled to visualize them by their formula names. A number of instruments of the Woodbury-Crandall and the Woodbury sets vary slightly in their formulas from those of the Black set given above. Teachers in a number of the colleges, modify instrument formulas to meet individual ideas and needs, specifying to the instrument manufacturers preferred specifications to be supplied for the college set. The tendency in modern instrumentation is to discard many of the larger sizes in the above formulae, or to have the manufacturers reduce the dimensions of some of them. Many modifications of the original Black formulas are recommended by the author and will be noted in their proper place.

ARRANGEMENT OF INSTRUMENTS IN THE OPERATING CASE

Instruments should be arranged in a definite order in the operating case and kept in the same place at all times, so that they may be instantly found when needed. This saves the time of the instructor and the student and makes for efficiency. The student or dentist who is not familiar with his instrument forms and who has not adopted a systematic method of arrangement in the operating case or cabinet is wasting probably one-third of his time searching for instruments needed. The method of arrangement will vary somewhat depending on the instruments included in the set and the individual preference of teachers.

In each drawer of the operating case may be placed a printed card, which fits the drawer and indicates the exact position of each instrument in the drawer. Fig. 253 is a photograph of a drawer from a student's operating case showing the card in position and the instruments in order, while Figs. 254 to 257 show some of the cards for individual drawers. The Case Placement Chart and the drawer cards are given the student at the beginning of his course and he is expected to observe the indicated arrangement at all times. This is a great time saver and is a part of the standardized system of instrumentation advocated throughout this work. The names and formulas of the instruments shown in these illustrations are merely suggestive and may be modified to meet the individual ideas of various teachers.

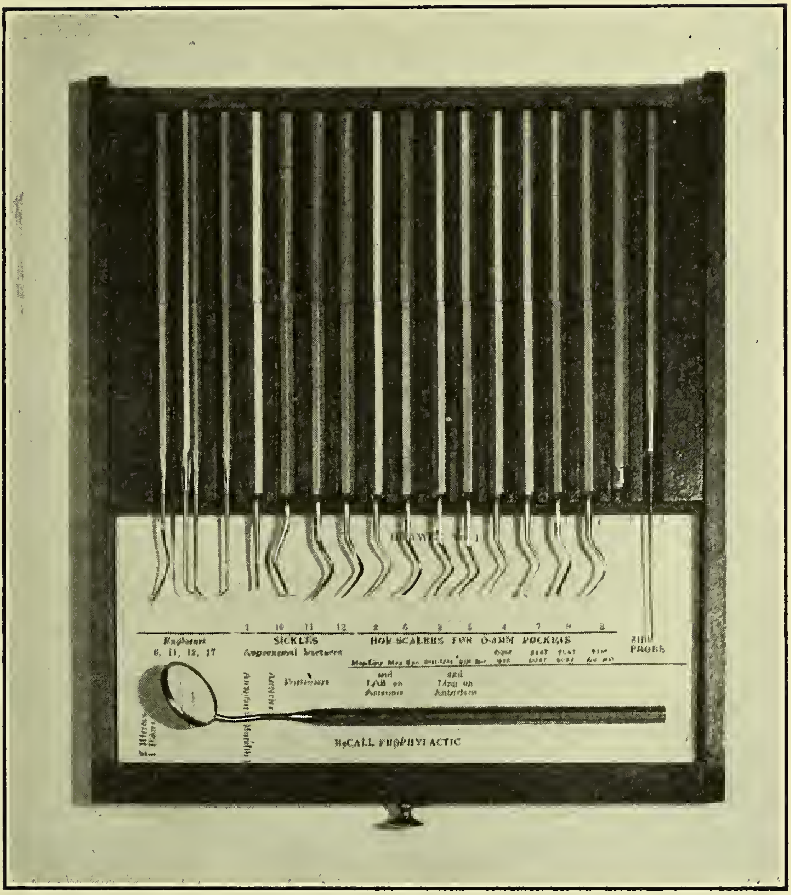


FIG. 253.—Drawer number one from student operating case, showing placement card and instruments in position.

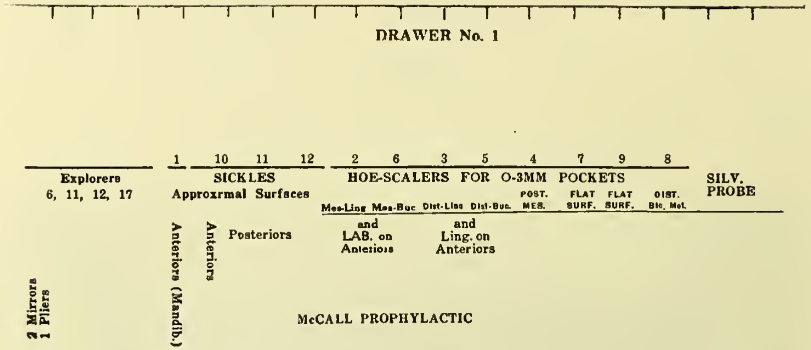


FIG. 254.—Instrument placement card for drawer number 1 of the instrument case.

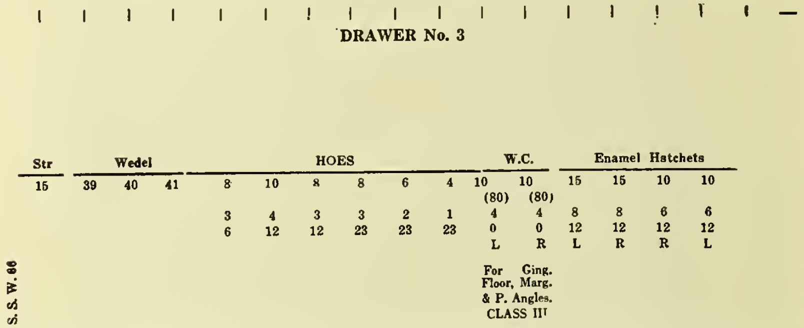


FIG. 255.—Instrument placement card for drawer number 3 of the operating case.

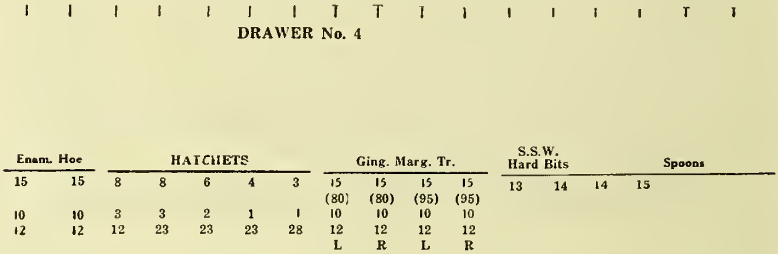


FIG. 256.—Card for drawer number 4.

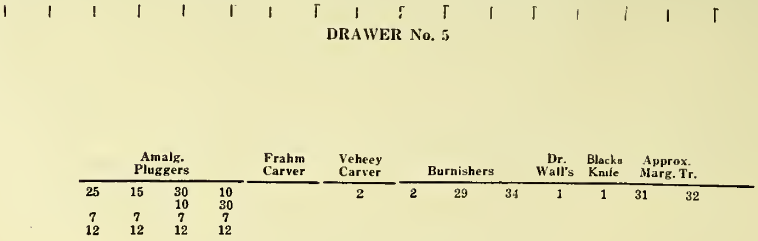


FIG. 257.—Card for drawer number 5.

CHAIR AND OPERATING POSITIONS

Posture at the chair is of great importance to the dentist because (1) it has a definite bearing on the correct performance of his operations; (2) it affects the comfort and cooperation of the patient; and (3) it concerns or influences the health and usefulness of the operator. If the chair is incorrectly placed, the accuracy, exactness and precision necessary to the performance of the operation is lessened, incorrect angles of force

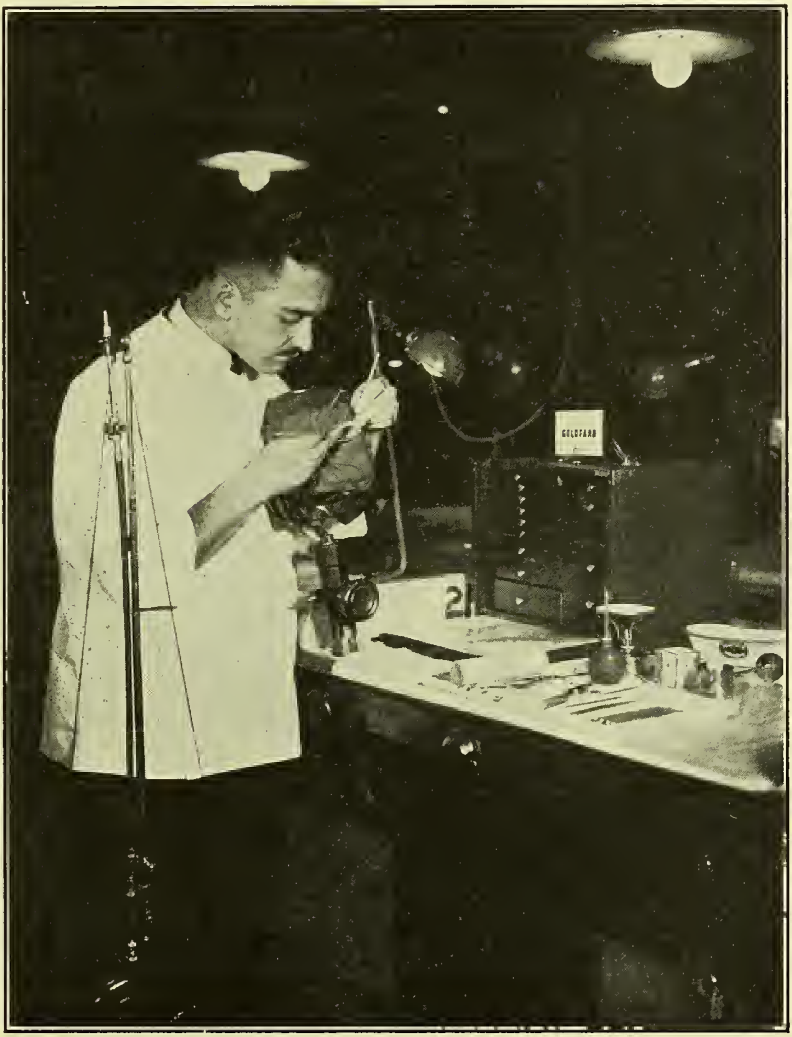


Fig. 258.—Students' work-bench in the operative technique laboratory, showing operating case, manikin, engine and instrument placement on the bench. The operating position is incorrect, since the manikin head is too high.

being brought into play in instrumentation, thus producing less perfect operations. The intelligent patient frequently is enabled through cooperation to greatly assist the dentist. However, if the chair is improperly adjusted and the patient is placed in an unnecessarily uncomfortable position not only is this cooperation likely to be lost, but actual interferences may be established. From this cause the patient's nerve force is often lowered and his resistive powers greatly reduced before the completion of the operation. Also the efficiency of the dentist will depend in quite a degree on the manner in which his own body is used. If in a state of health and used correctly, he should be enabled to operate eight hours a day with a minimum of strain and fatigue over a period of many

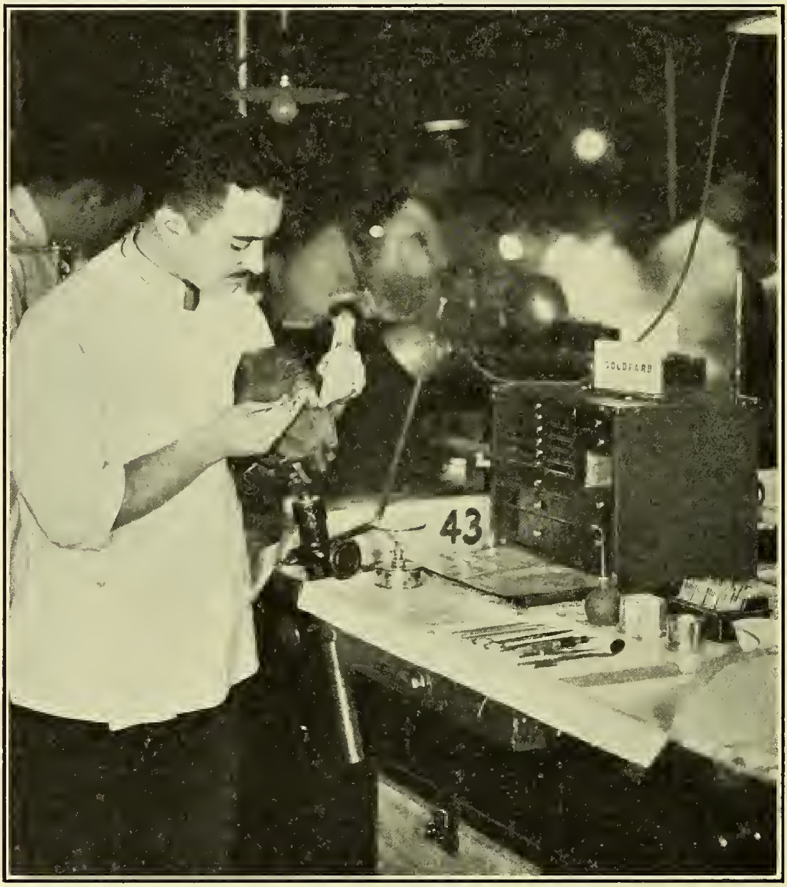


FIG. 259.—Student at work in the operative technic laboratory. The manikin has been lowered and the operating position is much better than that shown in Fig. 258.

years. If this is neglected, opposite results may be expected and his period of usefulness and productive power greatly shortened or lowered.

Dental practice is a sedentary occupation and frequently produces great strain on the physical and nerve forces of its devotees. Every effort should be made to eliminate unnecessary strain and to keep the natural forces of the body at the highest state of efficiency through adopting correct posture at the chair, avoidance of eye strain, and eliminating all deteriorating forces likely to reduce nerve power and physical endurance. The student obtains his first experience in operative procedure in the operative technic laboratory. In the early portion of the course, at least, the operations are performed at the work bench. Even here correct posture should be studied. Later, work on some form of manikin should begin. The manikin should be capable of adjustment so that similar positions to those to be later assumed at the chair may be studied and adopted. Figs. 258 and 259. Correct chair and operating positions, if acquired early in his career, will be of the greatest importance in their bearing on the future success of the student as a practitioner.

The correct **Position of the Operator** for examining and operating on the teeth may be described as follows.

First.—He should, as far as conditions will permit, stand in an upright position, both feet on the floor, with his shoulders thrown back and his chest forward to avoid the tendency to stoop-shoulders. The athletic position is of course, not admissible under all circumstances but it should be maintained as nearly as operating conditions will admit. Fig. 260.

Second.—The weight of his body would rest firmly on the balls of his feet rather than on his heels, with the feet slightly apart, both on the floor. The student should not acquire the habit of resting one foot on the chair lever. This is not only ungraceful, but throws the body out of balance, causing unnecessary curvature of the spinal column and congestion of the circulatory organs. Fig. 261.

Third.—The points of bodily contact with the patient should be as few as possible; as a rule only those secured by the correct application of the rest and guard. The patient should be adjusted in the chair so as to avoid the necessity for close bodily contact.

Fourth.—He should breathe deeply, slowly and naturally, through the nose, avoiding inhaling the patient's breath or exhaling into his face.

The correct **Position of the Chair** for examining or operating on the teeth is as follows:

First.—For the upper teeth, the chair should be tilted more or less backward (in order that a better view may be obtained) and elevated to a greater or lesser extent (depending on whether the anterior or posterior teeth are concerned) to suit the convenience of the operator. Fig. 262.

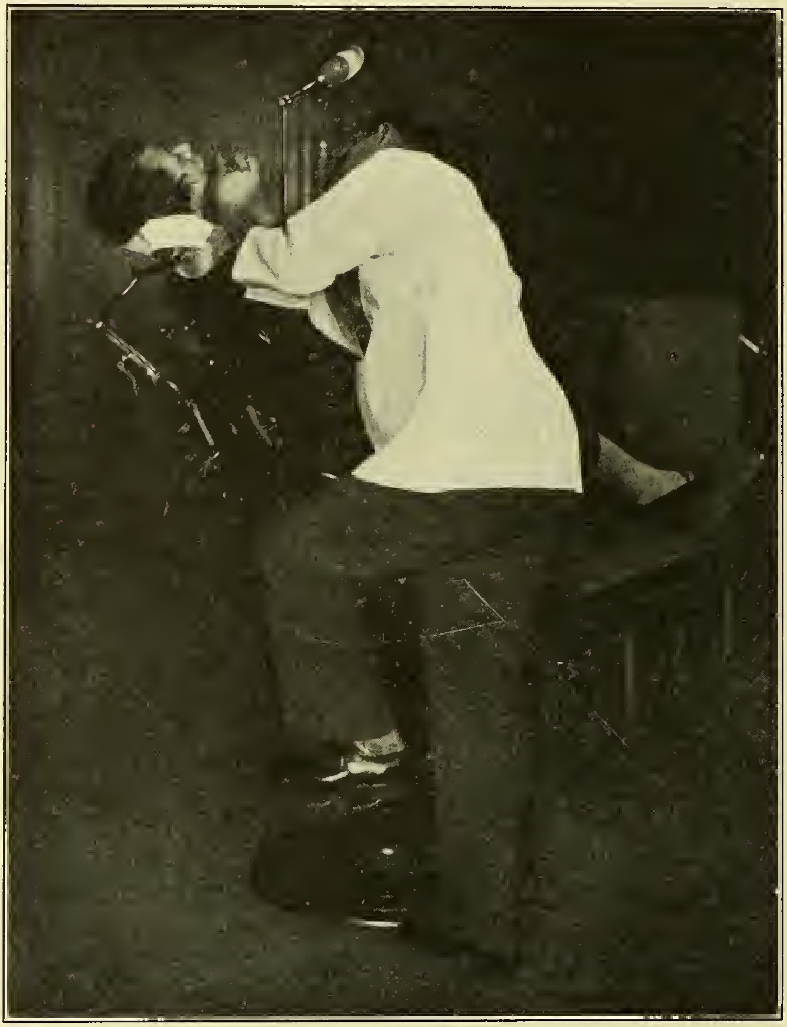


Fig. 260.—Incorrect operating position. The chair is too high, the head of the patient is too far back, the student's posture is incorrect, his body being off balance, and his left foot should be on the floor.

Second.—For the lower teeth the patient should be in a more nearly upright position so that the light may be thrown directly onto their surfaces, with the chair lowered. The mouth of the patient should be on a level with the lower half of the humerus of the operator when standing with the arm at the side. From the middle of the humerus to the elbow is adequate range for most dental operations, the chair being lowered or raised to keep the field of operation within this range, depending on whether the operation is on the upper or lower teeth. Fig. 263.

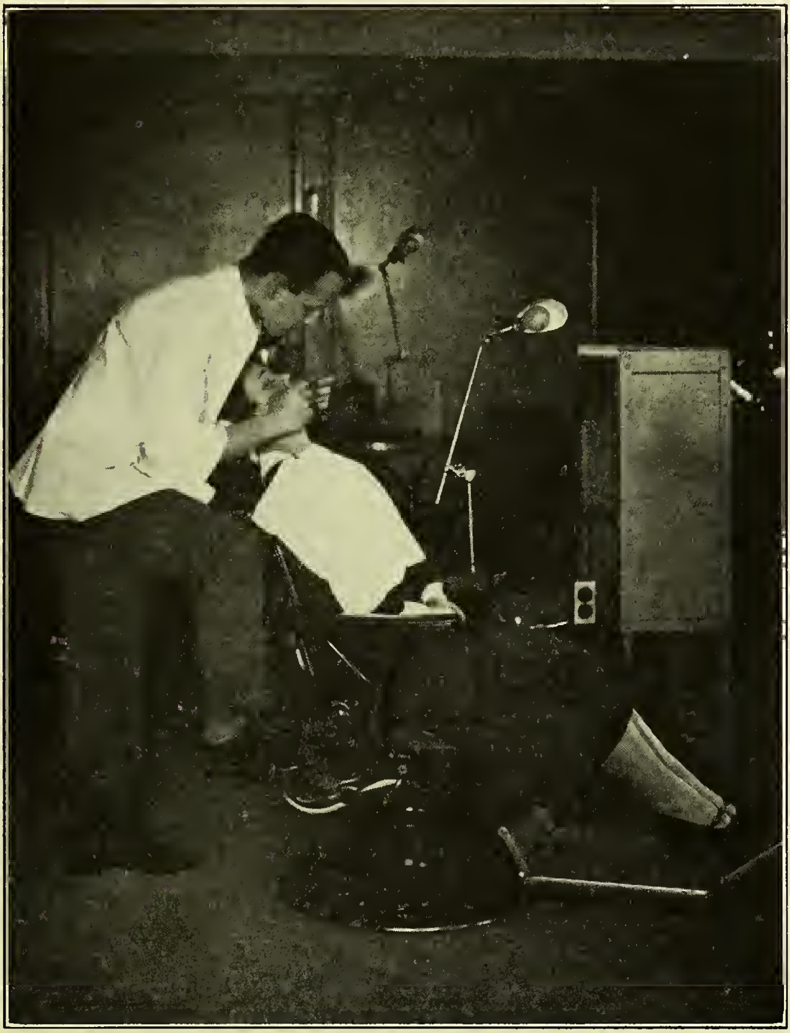


Fig. 261.—Incorrect operating position. The chair is too low and the patient's head is too far back for operations on lower teeth. The chair should be raised slightly, the patient's head should be placed further forward, and the student should assume a more upright position, with both feet on the floor.

The chair positions described in this work are those preferred by the author. In teaching they may be changed or modified according to the individual ideas of the teacher.

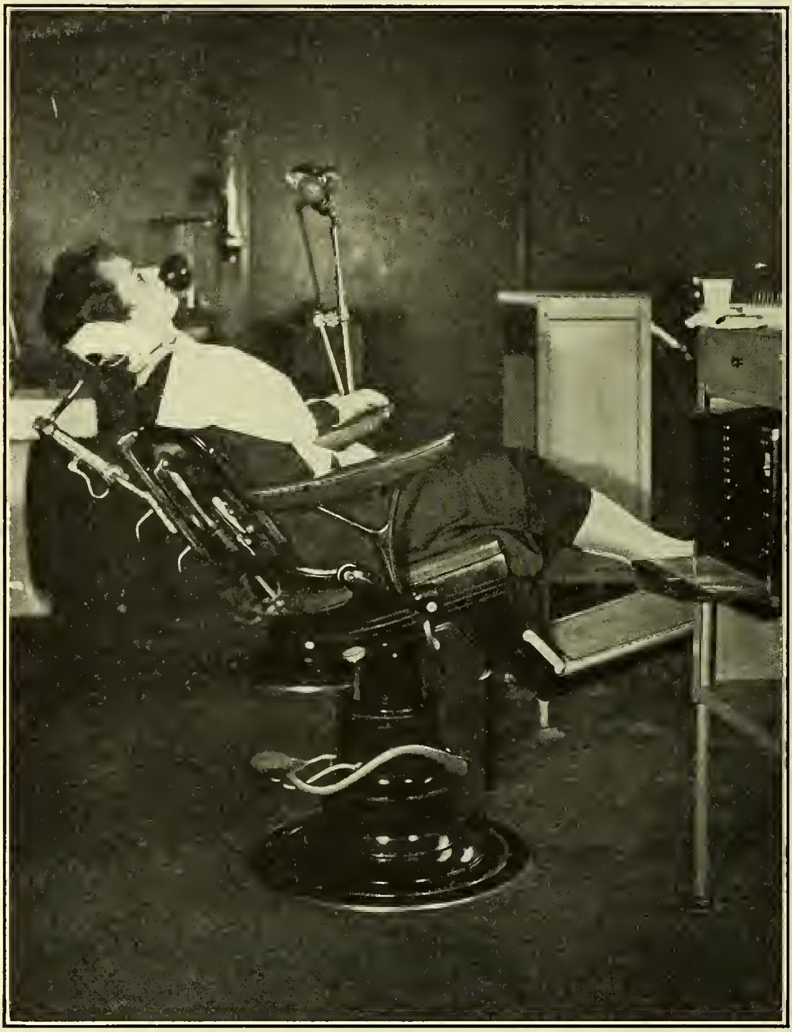


Fig. 262.—Chair adjustment for operating on upper teeth.

The **Adjustment of the Chair to the Patient** is also an important consideration. Modern operating chairs are so designed that nearly any adjustment desirable may be made to suit patients of any size or build. Special small chairs are available for practices catering to children. For dentists in general practice, the standard size of chair may usually be easily and perfectly adjusted to any size patient except very young children and even these may be fairly well taken care of by means of the extra foot rests, movable arms, special seats, and other attachments now obtainable.

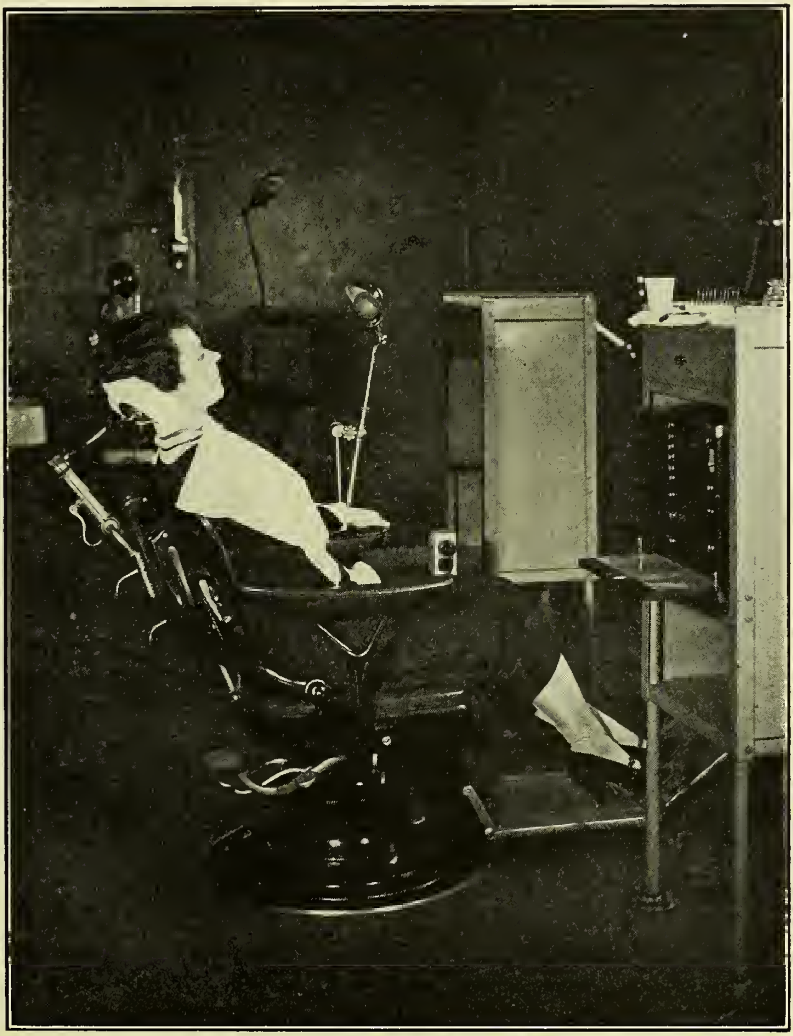


FIG. 263.—Chair adjustment for operating on lower teeth.

Before allowing the patient to be seated, a clean sterilized head-rest cover should be in place. The chair always should be placed at its lowest position and not tilted back. As soon as the patient is seated, the back rest should be adjusted to the height of the patient, tilting it slightly backward to allow the weight of the body to rest comfortably against it and allowing its top to be slightly below the level of the spines of the scapulae. Care should be taken to see that the lumber region (small of the back) is properly supported. If any adjustments of the arms are necessary to accommodate patients of unusual size, these should now be made. Care should be observed to see that the patient is enabled to rest the feet comfortably on the adjustable floor-rest or foot-board of the chair. A special foot-rest is usually provided for children on modern chairs. The head-rest should now be carefully adjusted to make the patient as comfortable as possible without interfering with the approach to the field of operation. If it is thrown too far backward, it will place the tissues of the neck on a strain and interfere with deglutition; if too far forward, the patient's head will be thrown out of balance, the chin will be lowered too much for easy access to the teeth and both patient and operator will be inconvenienced. The movable head-rest pads should support the head slightly below the mastoid region, with the occiput nearly on a level with the connecting cross-bar.

Usually the chair should be first adjusted as if for operations on the lower teeth, with the patient in a fairly upright position. After this is accomplished, it will seldom be necessary to change the position of the back rest. After placing a towel in position and securing it with the towel-holder, we are ready to proceed if the operation is for the lower jaw. If on the maxillary teeth, the entire chair (not the back rest) should now be tilted backward and raised to the proper height. The height will depend on the height of the operator and both height and tilt will vary slightly depending on whether the anterior or posterior teeth are to be reached. After the position for upper teeth is acquired, some slight adjustment of the head-rest may be necessary at the beginning or later in the operation.

It should be seen to that patients maintain the proper position in the operating chair. The tendency of many will be to slide down from this position after the chair is tilted, especially if they are so adjusted that their feet do not have a proper purchase on the chair. A proper and comfortable chair adjustment will tend to prevent this. However, if it occurs, the patient should be instructed in this regard and requested to maintain the proper position, else the ministrations of the operator will be seriously interfered with.

On the completion of the operation, the chair should be brought to its lowest position and tilted forward before the patient is dismissed.

This should be carefully and slowly done to avoid jarring the patient and to prevent damage to the tilting levers or chair. Patients should not be allowed to attempt to leave the chair until it is placed in proper position to enable them to easily and gracefully remove themselves, else a fall or injury may result.

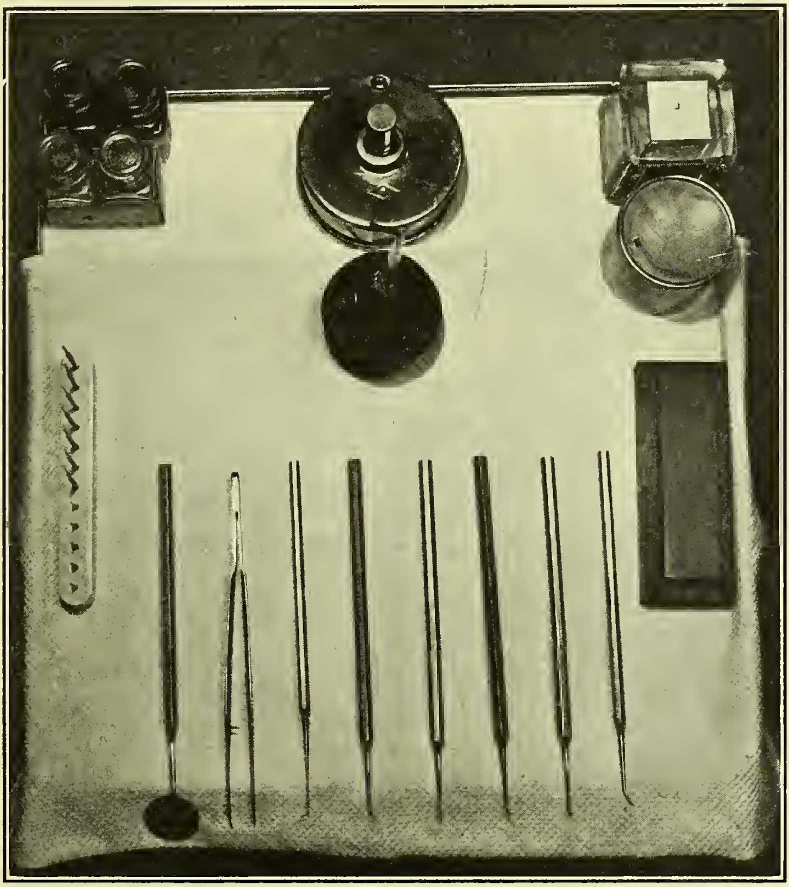


Fig 264.—Standardized arrangement of the student's operating bracket table, to be used at each chair in the operative clinic, before examination of the patient or beginning work.

In so far as possible, the instruments and all material to be used in the operation should be placed in the order of their use on the bracket or operating table before the operator proceeds. Fig. 264. The definite system of instrumentation described in this work, together with a knowledge of the instrumentation charts will enable the student to save his own and his patients' time as well as that of his instructors in this regard. It should not be necessary for students or instructors to search for the desired instruments. They should be at hand in full view and in proper order at all times. In active practice, the details incident to placing in and dismissing patients from the chair, sterilization and care of instruments and similar procedures are assigned to the nurse or assistant. An intelligent nurse will, by consulting the appointment book, case history and operating chart of the patient be enabled to save a great deal of valuable time if she is instructed in the use of the instrumentation chart. By referring to all of these, she should be expected to have the patient placed and all needed instruments in position before the dentist is ready to operate. The student in college should study and be taught these matters as important details of orderly procedure, since they have an important bearing on his future career. The place to begin this training is in the operative technology laboratory and it should be followed up as soon as clinical practice begins and be practiced until it automatically becomes a part of his daily routine.

POSITIONS AT THE CHAIR

The chair positions described in this book are those advocated by the author. Teachers in the various schools may, of course, adopt modifications to meet their individual preferences.

The fundamental operating positions at the chair are three in number which will be designated in this work as Numbers 1, 2, and 3. Each of these is divided into one each for upper and lower teeth so that they may be designated thus:

Position Number 1.—Right Side in Front.
  (*a*) Right side in front for upper teeth.
  (*b*) Right side in front for lower teeth.
Position Number 2.—Right Side Behind.
  (*a*) Right side behind for upper teeth.
  (*b*) Right side behind for lower teeth.
Position Number 3.—Left Side Behind.
  (*a*) Left side behind for upper teeth.
  (*b*) Left side behind for lower teeth.

Formerly a fourth position, namely, left side in front was occasionally used. This has been abandoned since the introduction of the modern operating unit.

In the adoption of all of the chair positions the following precautions should be observed:

1. The chair should be so placed that the operator will look *down* (not up) on the work. This is important to avoid eye-strain and improper posture in operating.

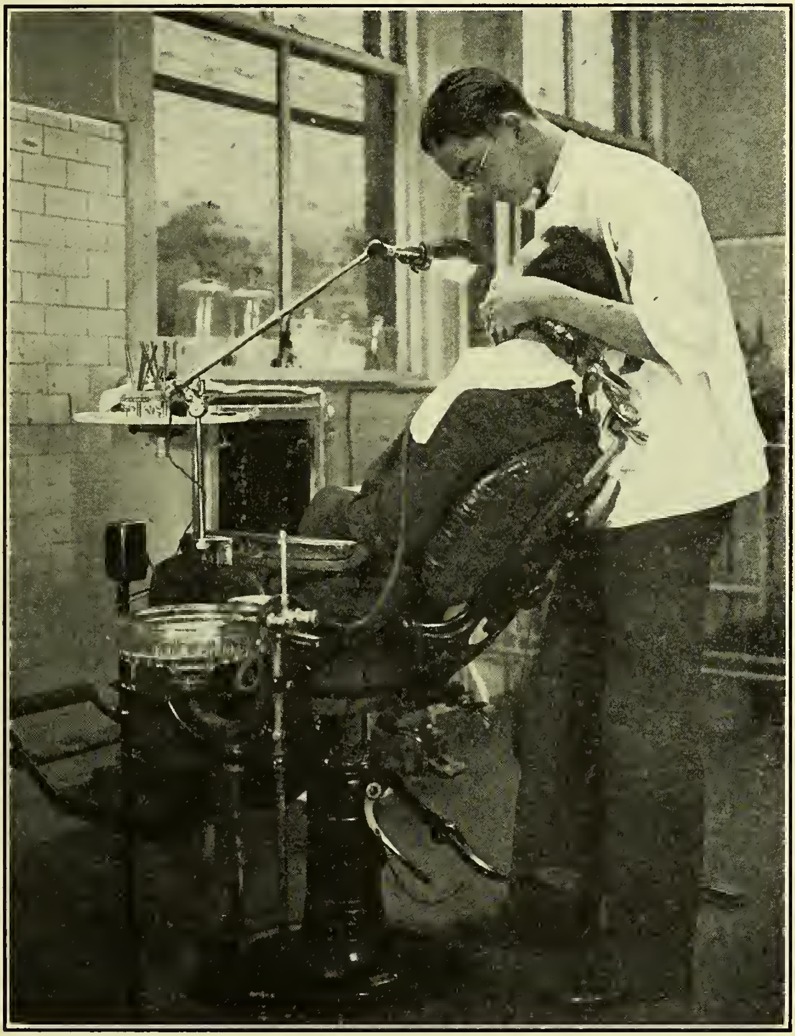


Fig. 265.—Incorrect right side behind position for lower teeth. The chair is too high, thus bringing the hands of the operator up into a tiresome position.

2. The chair should be so placed that the operator will not be compelled to work with his arms up. This would be a very tiring position and should always be avoided, as the student may readily learn by holding both arms in the air for a few minutes and noting how quickly the strain of such a position produces fatigue. Fig. 265.

3. Place the chair so that the various instrument grasps, rests and guards may be accomplished in so far as possible with the palms of the hands toward the operator or turned down. If the student will hold his right hand out for a moment with palm down, then turn the palm up, he will soon perceive how quickly the latter position tires him from the resultant strain on the muscles of wrist and fore-arm.

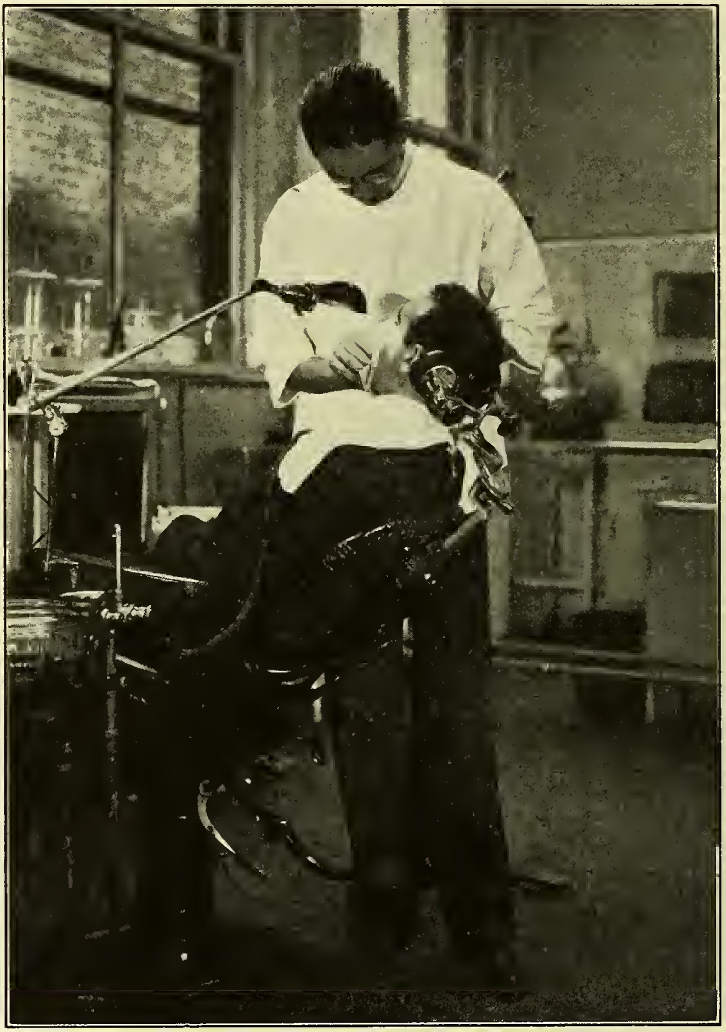


Fig. 266.—Right side in front. Good operating position.

4. Place the chair in and assume the position which will avoid the necessity for straining the eyes on the work. In many instances, various

stages of the work had better be done by reflection of the image in the mouth-mirror. Fig. 266.

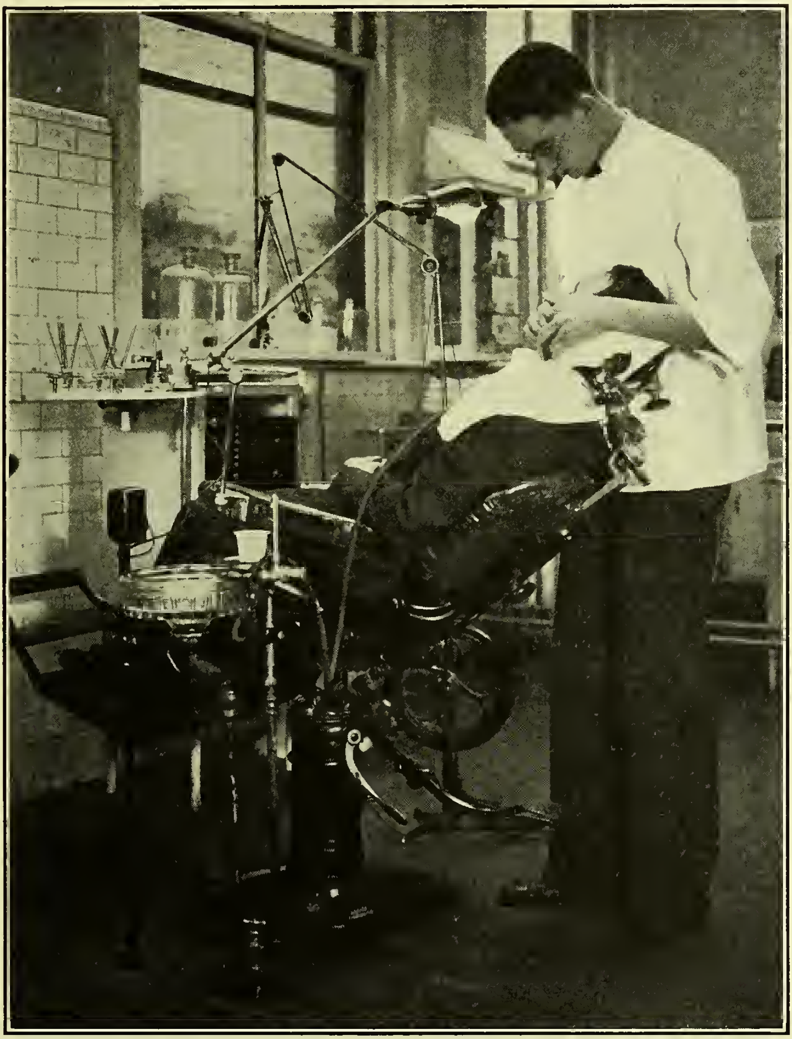


Fig. 267.—Right side behind position for upper anterior teeth. The chair is not quite high enough, the backrest is too low and the headrest is uncomfortable for the patient, resting too high on his head.

5. Do not place the chair too low with the resultant necessity to bend over too far. This throws the body out of poise, interferes with normal respiration and circulation, produces "stoop-shoulders," increases fatigue and eye-strain. Fig. 267.

6. Change positions occasionally for the rest which this procedure gives. In tedious or difficult operations, a temporary change of position to the opposite side of the chair will often afford relief from muscle and nerve strain.

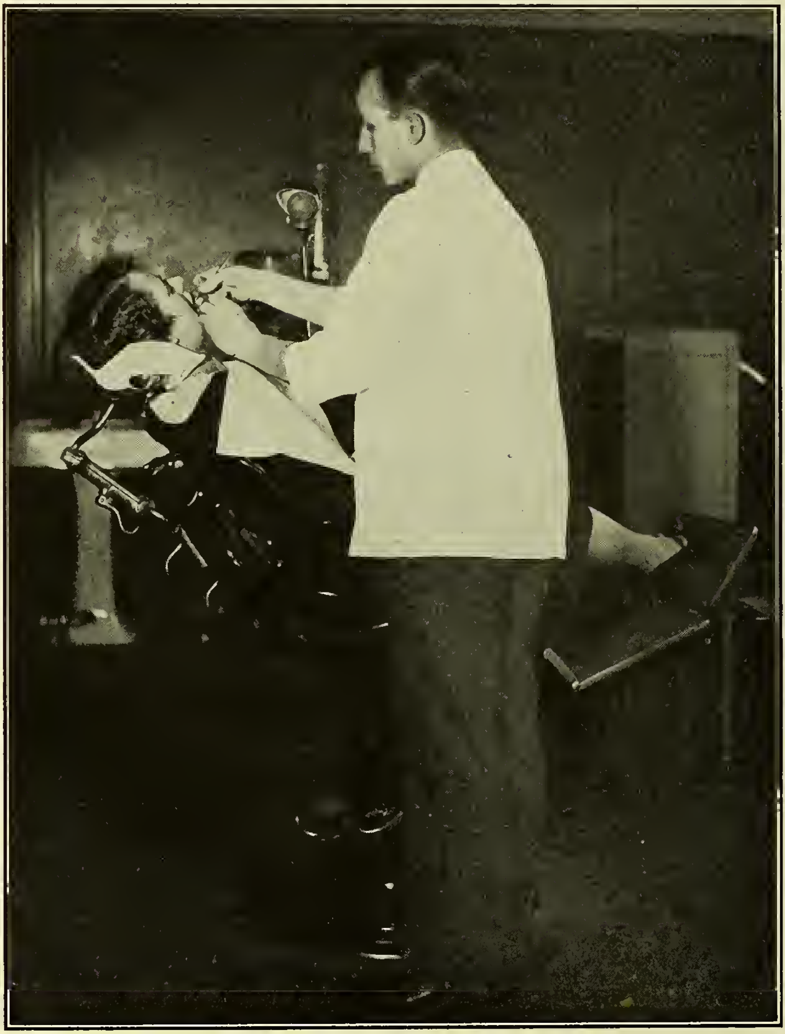


FIG. 268.—Right side in front position for upper teeth. Slight modification may be made, depending on the tooth to be operated upon and on the nature of the operation.

7. Always see that there is adequate light on the operating field. The illustrations herewith presented represent these fundamental chair positions. They should be closely studied, adopted if possible, as soon

as work on the manikin is begun and closely followed by clinical work at the chair until they become a fixed habit. These, together with the finger positions to be described have a very definite and important bearing on the acquistion of a thorough and efficient technical procedure, on the preservation of the health of the dentist, on the elimination of fatigue and on the prolongation of his period of usefulness.

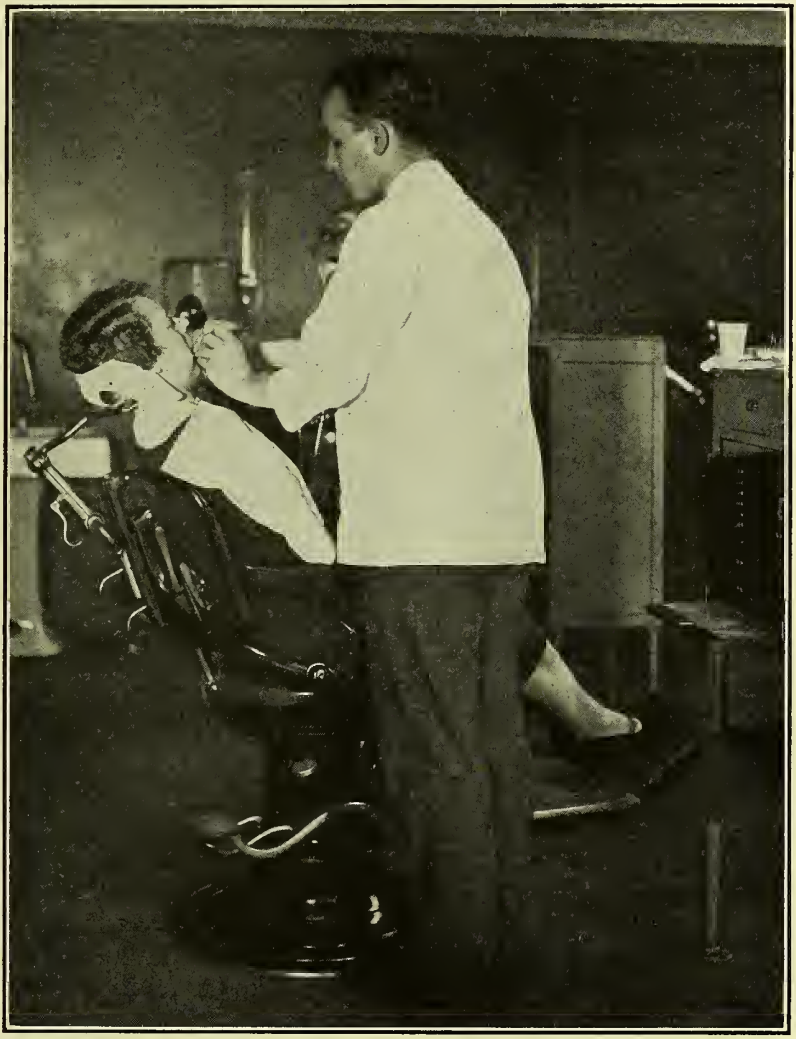


FIG. 269.—Right side in front position for lower teeth. The chair may be raised, if desired, depending on the tooth operated upon and the nature of the operation.

Position Number 1.—Fig. 268 illustrates *the right side in front position for the upper teeth.* This is an important one for many operations on the *upper* teeth, both anterior and posterior. In this position, both hands of the operator are in front of the patient, the entire chair is tilted backward (cradled) to throw the light on the field of operation, and elevated so that the oral cavity is on a level with the middle of the humerus of the operator. Fig. 269 shows the Number 1 *right side in front position for lower teeth.* Both hands are in front of the patient, the chair tilted forward to throw the light on the operating field and the mouth is

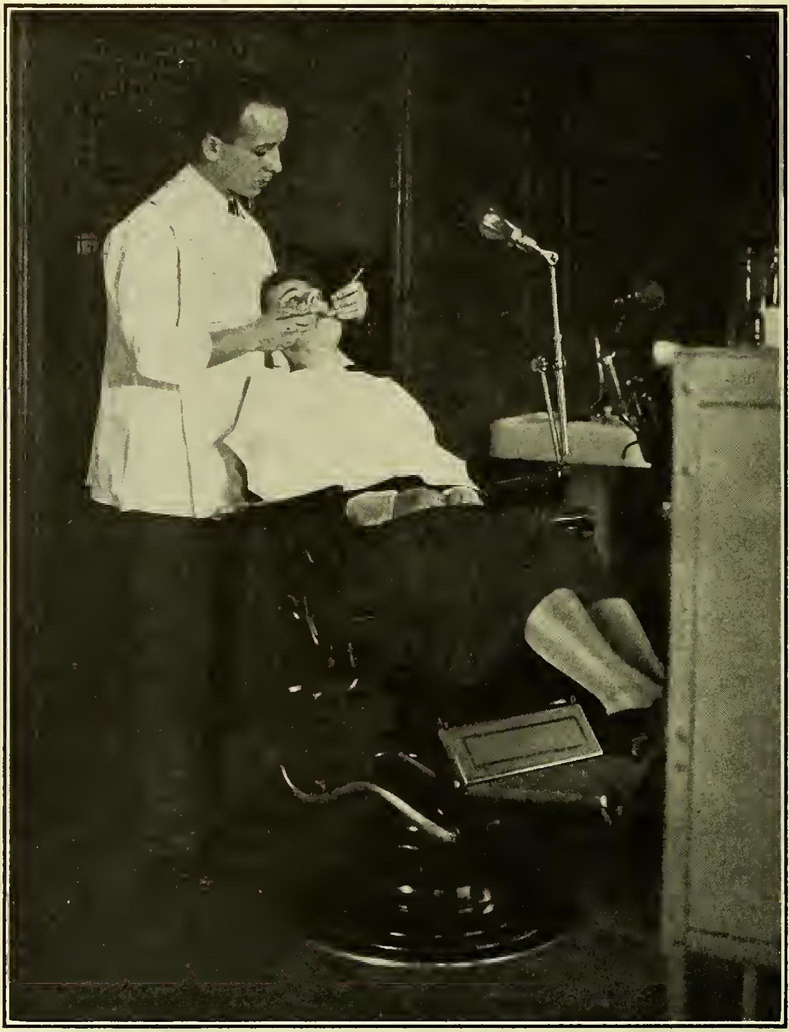


Fig. 270.—Right side behind position for upper teeth. The chair may be slightly raised for convenience, if desired, depending on the location and nature of the operation.

opposite the right elbow of the operator. This position is available for many operations on the teeth of the lower jaw, anterior or posterior, right or left.

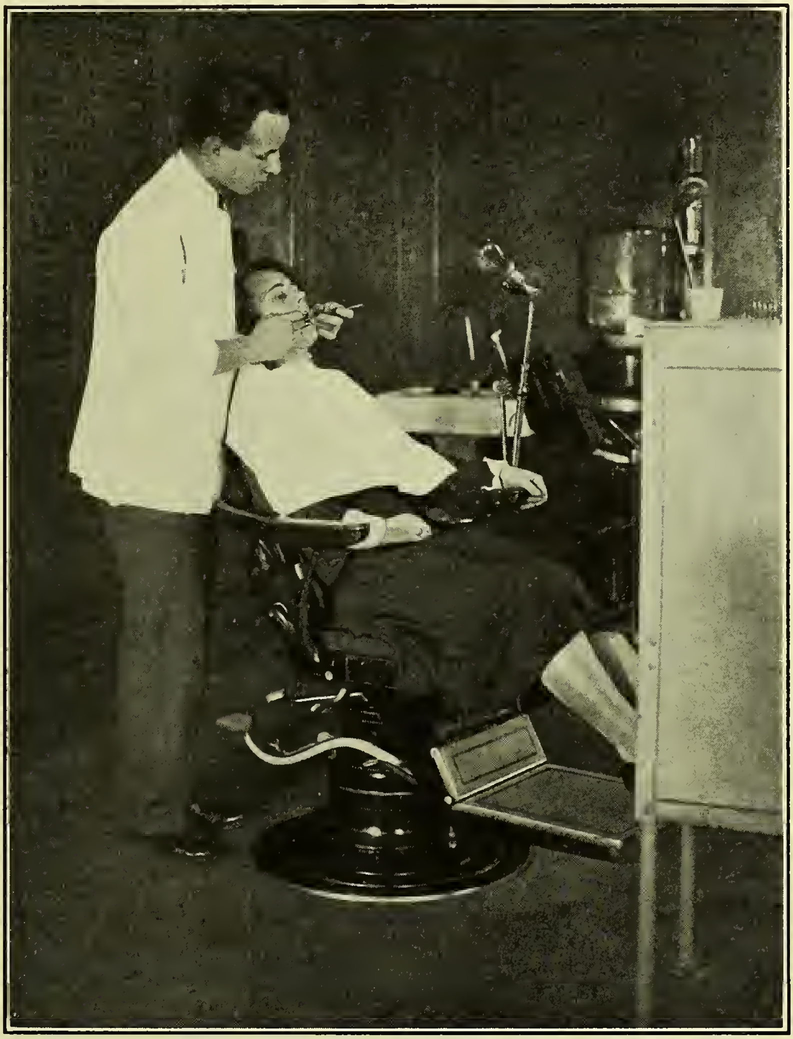


FIG. 271.—Right side behind position for lower teeth.

Position Number 2.—*The right side behind position* is most frequently used and in many instances is the most convenient for operations on both upper and lower teeth. It is assumed by standing behind and to the right side of the patient, the left arm being thrown around and to the left side of the patient's head. The right side behind position for *upper* teeth is illustrated in Fig. 270. It is available for the majority of the operations on the maxillary teeth, particularly those of the left side, and for anteriors, although the previous position, right side in front, will be found

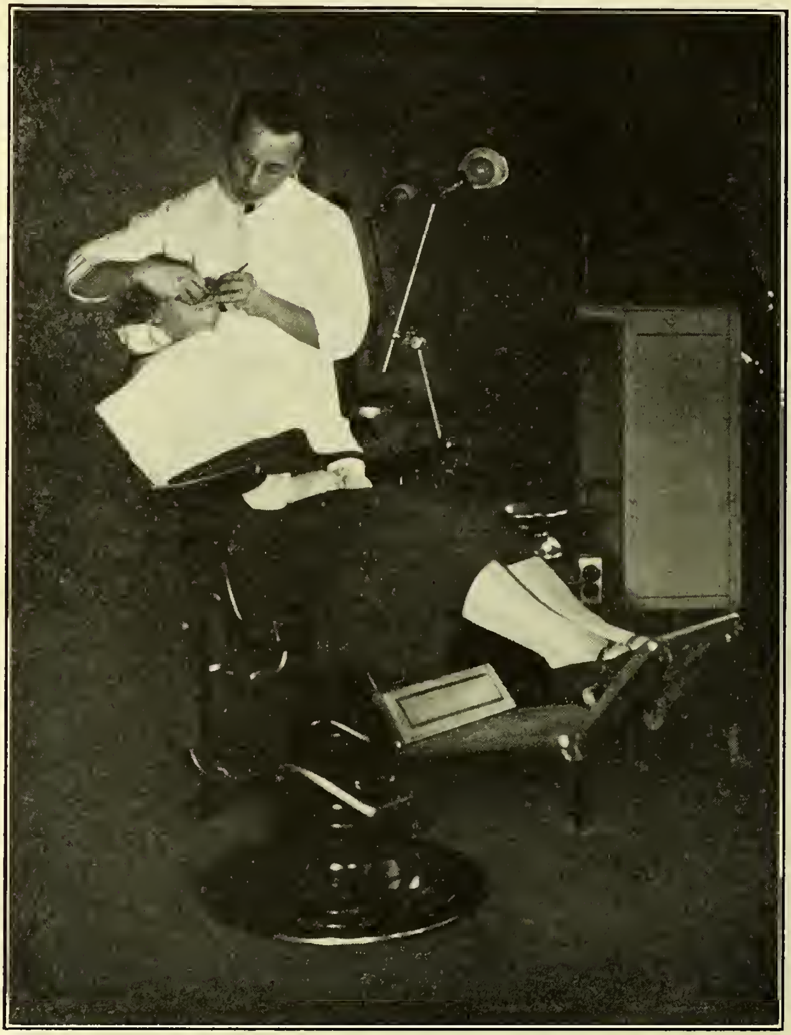


FIG. 272.—Left side behind for upper teeth.

more convenient for certain steps in cavity preparation, insertion of fillings and other procedures, depending on the tooth operated upon. Fig. 271 depicts the right side behind position for *lower* teeth, particularly useful for many operations on the lower anteriors and teeth of the left side. It is also valuable for reaching the buccal surfaces of the lower teeth of the right side. The positions, Numbers 1 and 2 should be interchanged frequently, the operator stepping forward or backward as is most convenient to obtain ready access to the operating field and to secure the needed finger rest for the work in hand.

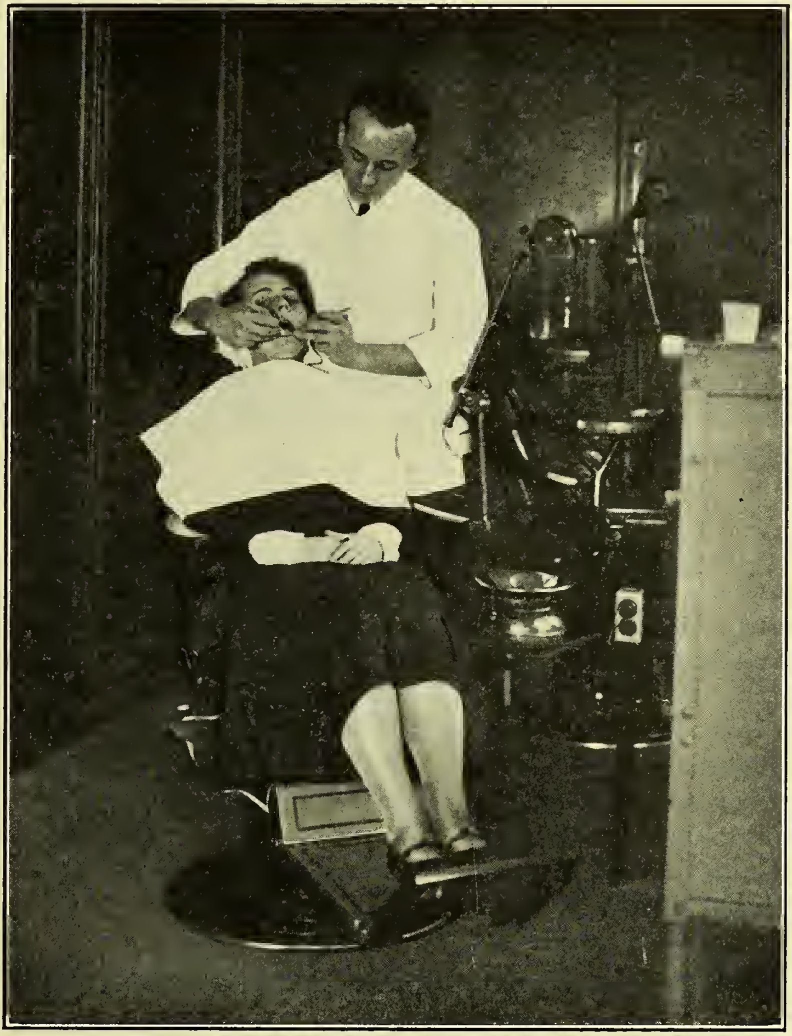


FIG. 273.—Left side behind position for lower teeth.

Position Number 3. *Left Side Behind.*—Moving over to the left side of the chair occasionally for a few moments to perform some definite short part of the work will be found convenient. It will also secure a needed rest for the operator and temporary relief from the fatigue of a prolonged or difficult operation. Figs. 272 and 273 illustrate this position for upper and lower teeth respectively. It is seldom used except in special cases and usually for short periods of time. For reaching the lingual surfaces of the upper right bicuspids and molars, the occlusal surfaces of the lower right bicuspids and molars, and the buccal surfaces of both upper and lower posterior teeth, it may occasionally be resorted to.

The fundamental chair positions illustrated will be somewhat modified to suit individual cases, operations, and positions in the mouth. It is both unnecessary and inadvisable to burden the mind of the student with definite rules for the adoption of each of these positions for definite cases. They should be closely studied, intelligently practiced as soon as possible and their use continued until they become an important part of his routine procedure. Their correct use, with modifications to suit the various angles of approach to different localities in the mouth will lead to increased efficiency and greater productive power. In many instances, the position and the work will be improved and made easier by turning the head of the patient to the left or the right for easier and more ready access.

FINGER POSITIONS

The various instrument grasps, rests and guards have been previously mentioned. It is now necessary that the use of finger positions be more definitely and fully discussed, since they play an important part in the development of the instrumentation with which the student must become familiar. Most of the work in operative procedure is performed with hand instruments. The use of the round, inverted cone and fissure burs in the dental engine has a limited but definite place in the preparation of cavities. Other forms of burs, drills, stones and discs are used for polishing fillings and other procedures; but in the correct formation of the plane surfaces, definite line and point angles in modern cavity preparation and for cutting and planing enamel, the various forms of chisel, enamel hatchet and excavator are largely used.

Use of the Lever.—In the use of hand instruments, the adoption of the system of levers, as studied in physics should be resorted to as far as possible, in order to steady the hand to the work and to increase the power of the thrust. Fig. 274. In science, what is called *work*, consists largely in putting matter in motion. In doing this some *resistance* or opposing force must be overcome. The work to be done varies in amount and difficulty, depending on the resistance offered and the *distance* intervening. Resistance is equivalent to opposing forces. The rate of accomplishing the work is called power. The value of an agent used to accomplish work depends on the rate at which it can do the work. Work is always done at the expense of energy. The exercise of energy produces stress or strain on the individual or the machine performing the work.

A machine is an instrument by which energy can be advantageously used to do work. There are six simple forms of machine. All machines, however complicated, are composed of a number of these simple forms, namely, the lever, the pulley, the wheel and axle, the inclined plane, the screw and the wedge. The efficient use of hand cutting instruments usually involves the use of the lever, one end of which is an inclined plane or wedge. The hand and the instrument (lever) are really a machine used for accomplishing work, the inclined plane (chisel, hoe) or the wedge or double inclined plane (hatchet), being placed in contact with the matter to be moved. The levers usually utilized are of the first and third *classes*. The *weight* is at the blade, the *power* is at the portion of the shank grasped by the fingers, and the *fulcrum* is obtained by means of the fingers used for a rest. Figs. 275 and 276 illustrate a lever of the first class in which the fulcrum is placed between the weight and the power. Figs. 277 and 278 depict levers of the third class in which the power is placed between the weight and the fulcrum. A study of the photographs of finger positions will reveal the manner of their utilization in efficient operating. In the use of these levers, the working point of the instrument is the load, the shaft and shank grasped in the fingers are the power, and the fulcrum is usually obtained by means of the second or third fingers, sometimes also the fourth finger of the right hand. In some instances, the instrument may also be steadied by application of the fore-finger of the left hand to its shank. In other cases, an additional

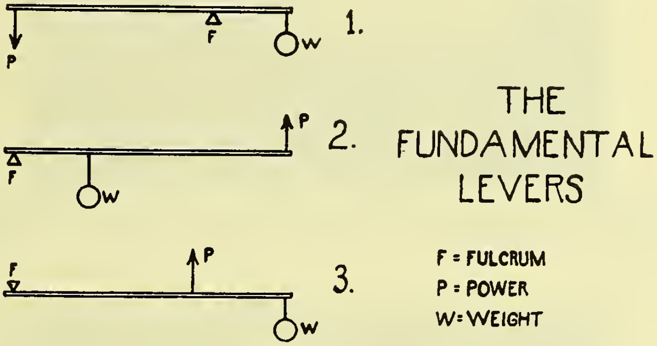


FIG. 274.

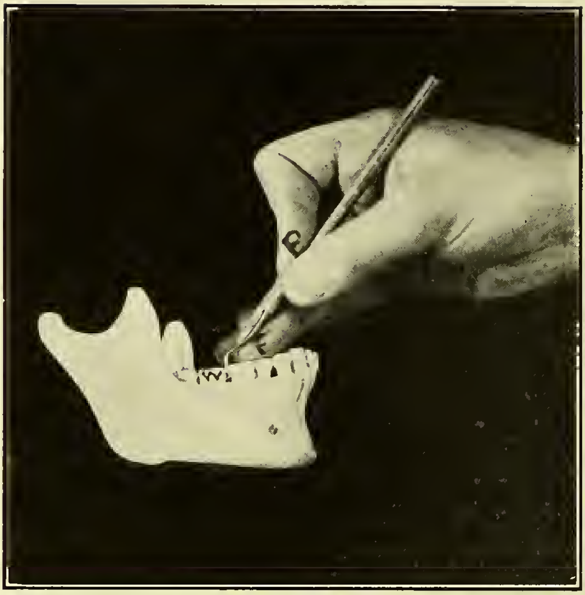


FIG. 275.—Illustrating a lever of the first class. A modified pen grasp in which the second finger is used to steady the instrument and also to act as a fulcrum or rest. (Courtesy of Dr. Finn J. Bronner.)

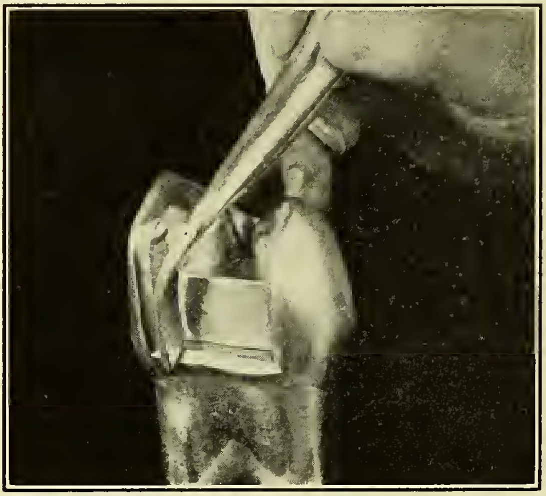


FIG. 276.—Illustrating a lever of the first class out of the mouth, with a bicuspid and an instrument (gingival margin trimmer) much enlarged. The hand is normal size. The fulcrum is at the third finger. (Courtesy of Dr. Finn J. Bronner.)

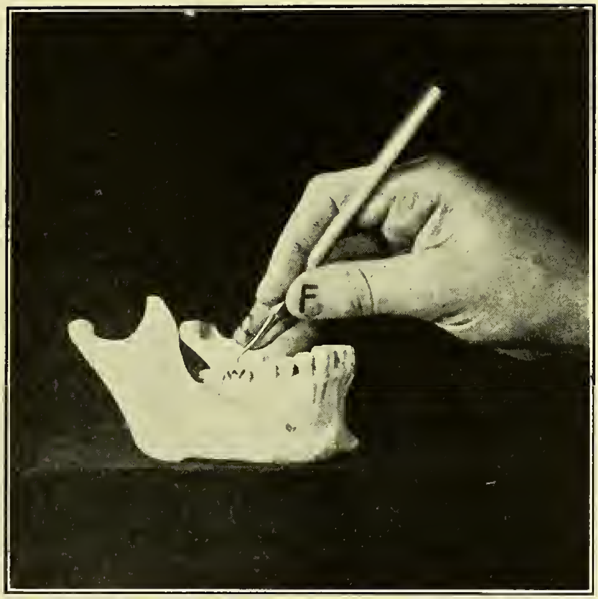


FIG. 277.—A lever of the third class. A modified pen grasp in which the power is being applied by pressure of the second finger, while the fulcrum is obtained by the third finger and also by the thumb. (Courtesy of Dr. Finn J. Bronner.)

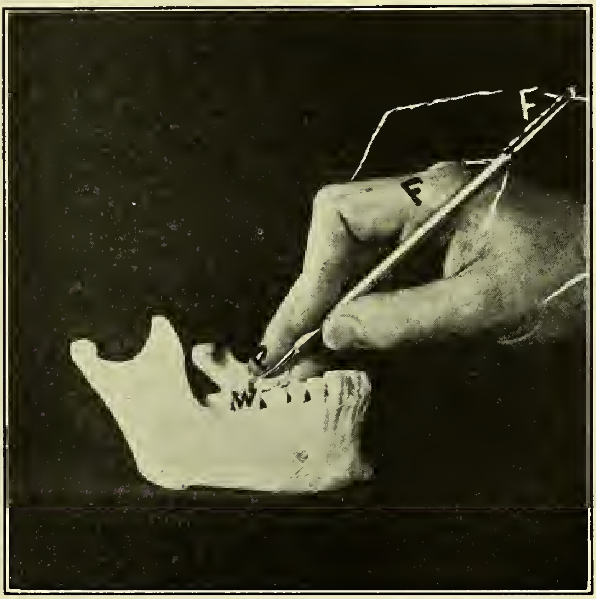


FIG. 278.—A lever of the third class. A modified pen grasp, the power being applied by the second finger, while the fulcrum is obtained between the crotch of the thumb and first finger and also by the third finger. (Courtesy of Dr. Finn J. Bronner.)

fulcrum may be obtained by resting the length of the blade or some part of the shank of the instrument on the tooth being operated upon or on an adjoining tooth. This will greatly increase the power and further control the instrument. Free-hand operating should be avoided as far as possible, since, although a greater range of movement is obtained in free-hand operating, there is increased tendency to slipping of the instrument and the force of thrust necessary to many procedures is greatly diminished through absence of a fulcrum for application of the power. Through the use of correct chair positions, the cases in which a proper fulcrum (rest) may not be obtained on the teeth or alveolar process are in the minority. Rests should be found in so far as possible on the hard tissues of the same jaw being operated upon and as close to the tooth receiving attention as convenient. Where this is impossible, they may be frequently found, though not so secure, on the teeth or gingival tissues of the opposite jaw. Rests on the soft tissues of the face are insecure, inefficient and often unnecessary. The shorter the distance between the fulcrum and the weight, the greater the power.

The parts should be guarded from injury and steadied by the thumb and fingers of the left hand. Particularly is it necessary to steady the lower jaw when the operation involves the mandibular teeth. The lips and cheeks should be held away by the same means or by the use of the mouth mirror. The mirror is valuable for this purpose as well as for reflection. Whenever it is used, however, the left hand should be steadied if possible by obtaining a rest by means of the second, third or fourth fingers, else the edge of the mirror may be forced against the gingival or other tissues unawares, with the production of pain. Operating without a guard, the left hand not being utilized, as sometimes seen with inexperienced students or careless operators, should not be tolerated. Neither should the left hand be placed on the top of the head of the patient as is occasionally observed with students.

No attempt will be made to burden the mind of the student with fixed rules for the use of finger positions. The use of the lever, as applied in physics, is more fully described in the chapters on "Preparation of Cavities," when the student will be in a better position to understand it. The accompanying illustrations show a few of the finger positions most frequently used and will enable him, through observation and practice to learn to adopt others which will be of assistance to him in his work in the operative technic laboratories, the clinics and later in actual practice.

Bibliography

1. Pleasure, Max: Dental Items of Interest, vol. XLX, Jan. 1928, p. 11.

Black, G. V.: "Operative Dentistry," vol. II.
Cooley, L. C.: "Students' Manual of Physics," American Book Co., 1897.
Deming, H. G.: "General Chemistry," Jno. Wiley and Sons, Inc., 1923.
Clark, D. G.: Recent developments in stainless steel, Year-book American Iron and Steel Institute, 1925.
Nobbs, Arthur H.: Posture at the dental chair as related to the dentist's health, Jour. Amer. Dent. Assoc., Nov. 1928, p. 2132.

CHAPTER VIII

HYGIENE, LIGHT AND ASEPSIS FOR THE DENTIST

Dentistry is a sedentary occupation and is not particularly conducive to the maintenance of high standards of health or to prolongation of the life expectancy of those who practice it. Standing at the chair year after year for seven or eight hours a day, working in constrained positions and under a nervous tension, followed by additional work in the laboratory is likely to undermine the health, wreck the nervous system, lower the efficiency and shorten the productive period of the dentist, unless the danger is recognized early and measures instituted to prevent it. Many practitioners, careless of their personal health and failing to realize the stress of active practice, early succumb or seek other vocations, while others, seemingly careless in this regard and possessing unusually strong constitutions, often continue in practice for many years and live to a good old age. The average man or woman should seek methods to maintain his resistive powers and the profession at large is beginning to give serious thought to personal health measures in and out of the office, relaxation, exercise, vacation periods and similar procedures. This is resulting in an increase in the health standards and efficiency of the great body of men and women in active practice.

It is important that the student should learn of these measures early in his college course, since the study as well as the practice of dentistry is also a sedentary occupation. Attention to bodily health, care of the eyes, correct posture at the chair and aseptic procedures in operating will produce a higher type of student and lead ultimately to a higher type of practitioner. Aseptic operating methods and correct sterilization of instruments serve to protect the dentist from disease as well as acting as a safeguard to the patient. They should be learned and put into practice early in the course in Operative Dentistry; hence they are discussed at this time under the following headings:

1. General health measures.
2. Hygiene in classroom, laboratory, clinic and operating room.
3. Management of light and care of the eyes.
4. Aseptic methods in operative dentistry.

GENERAL HEALTH MEASURES FOR THE DENTIST

A healthy mind in a healthy body is necessary for the highest type of scholarship during student life and in the years which follow. Regular exercise, plenty of fresh air and sunshine, daily baths, care in regard to the diet, keeping the eliminative organs active and securing a sufficient amount of sleep are important measures for maintaining efficiency. Setting-up exercises, if not too strenuous, deep breathing followed by a bath or shower, should begin the daily routine. A brisk walk to the school or office will help to put the body in a healthy glow and stimulate the respiratory, circulatory and other organs. Constipation and intestinal toxemia should be avoided, since it saps the energies of mind and body. The bowels should move several times a day. The diet should be given careful attention to avoid digestive disturbances. In it should be included a sufficient amount of roughage to stimulate the functions of mastication and peristalsis. An average of at least eight hours sleep is necessary for most individuals. This varies with age and temperament. A sufficient amount should be obtained to enable one with the above mentioned procedures to begin the day's work with optimism and confidence.

The dentist should be the clean man of his community. Great care should be given to his personal appearance. Attention to regular and frequent changes of linen, a clean shaven face, clean, healthy mouth and teeth, absence of mouth and body odors, regular manicuring of the hands and nails, neatly pressed clothing and well cared for shoes have an all-important bearing on the development of his personality. Needless to say that an attractive personality is an extremely important asset in establishing a good reputation in the minds of fellow students, teachers, patients and all with whom contact is maintained. The breath and hands should be kept free from the odor of tobacco, which is very disagreeable to many patients. Halitosis and unpleasant body odors have been the immediate cause of the failure to attain success of many dentists. The hands should be given great care and manicuring instruments should be a part of the dentist's equipment. Rough laboratory work does not tend to produce and maintain the soft, supple, well cared for hands necessary for the dentist operating in the mouth and performing operations requiring delicacy of touch and manipulation.

Attention has been previously called to the importance of correct posture at the chair. This has a definite bearing on the maintenance of health standards for the dentist, as well as on the efficiency of his operative procedures. Incorrect posture and operating positions are likely to strain the supporting skeletal frame and result in early tiring and exhaustion of the musculature concerned in the postural equilibrium of the body. This in time usually results in derangement and obscure ailments of the viscera, early production of fatigue toxins and loss of reserve strength. Circulatory, respiratory, digestive or intestinal disturbances are likely to follow. Back ache, stoop-shoulders, constipation, headache, eye-strain and other ailments of the dentist may frequently be due to poor posture. Correct posture will help to prevent or eliminate this condition, since it distributes the weight of the body in such a way that the strain on the skeletal and muscular framework is minimized, the pull of gravity on the postural muscles is diminished and functional derangements of internal organs from these causes are prevented.

HYGIENE AND LIGHT IN THE LABORATORY, CLINIC AND OPERATING ROOM

The maintenance of proper light and correct hygienic conditions in the laboratory, clinic and operating room is of extreme importance. This should be borne in mind while in college and in the selection of a location after graduation. Many dentists today are practicing their profession in rooms that are poorly lighted, imperfectly ventilated, and with unsanitary heating and plumbing arrangements. These conditions must necessarily lower the efficiency and the productive power and shorten the period of usefulness of those who are working under them.

The average dentist spends one-third or more of the productive period of his life in the operating room and if his surroundings during that time are of an unhygienic nature, or if he is working under conditions tending to the production of eye-strain, he will be the sufferer sooner or later. Many young men have entered the practice of dentistry before having matters of this nature brought to their attention and have been compelled to learn of them through bitter experience.

The eyes are one of the principal assets of those following the profession of dentistry and since they are possibly the most delicate organs of the entire body, they should not be neglected. The student or dentist should see to it that he is working at all times in a light which is not productive of eye-strain and he should be careful, if he suspects a possibility of beginning eye trouble, to consult a competent oculist at once.

The maintenance of proper hygienic conditions and lighting arrangements is important for preservation of the health and eyesight and prolongation of the period of usefulness of the operator. The chief conditions essential to the ideal operating room for maintenance of health are:

First.—Proper ventilation at all times.

Second.—Admission of an abundance of sunlight occasionally during intermissions.

Third.—Modern heating arrangements.

Fourth.—Sanitary plumbing.

Fifth.—Correct exposure of the operating window.

Sixth.—Proper lighting facilities.

In ventilating the operating room, the windows should be opened sufficiently to allow a constant supply of fresh air, both in winter and summer. At the same time, neither operator nor patient should be directly exposed to a draft. The frequent admission of sunlight is important, because sunshine is a great purifier and a foe to germs and disease. The operating room should be one which is capable of being flooded with sunlight several times a day.

The question of proper heating arrangements should be given due consideration. The room should be maintained at a temperature of 68° to 70°F. in winter. Overheated rooms lower the efficiency and productive power of the operator. Electric fans, properly placed to avoid drafts, should be kept running during hot weather. Also, they will occasionally be useful in ventilating overheated rooms during the winter. Hot air furnaces are objectionable from the fact that they often supply air from unclean, damp cellars frequently contaminated with sewer gas and dust, consequently, hot water or steam is the preferable mode of heating.

Sanitary plumbing is also an important consideration in order to protect operator and patient from the dangers of unclean and germ-laden water and the inhalation of noxious sewer and illuminating gases. Supply and drain pipes should be freely exposed to view, all drain pipes properly trapped, and gas pipes and fixtures frequently inspected for possible leakage.

The question of the best *Exposure* for operating is a debatable one. Some operators prefer a direct northern light. The disadvantage of this exposure is in the fact that after the early morning hours the sun is largely excluded and sufficient light for operating is not always obtained. The ideal arrangement in the opinion of many, is a corner room with two windows, one of which faces the east and the other the south. With the chair facing the east window and the south window at the operator's back, an abundance of light is present at all times, while the sun will not be a disturbing element either in the morning or afternoon. Fig. 279.

The following precautions should be observed in regard to light in an operating room.

First.—Avoid bright, glazed or polished walls which reflect the light into the operator's eyes; rather select light brown and grey colors which are more restful and prevent fatigue and eye strain.

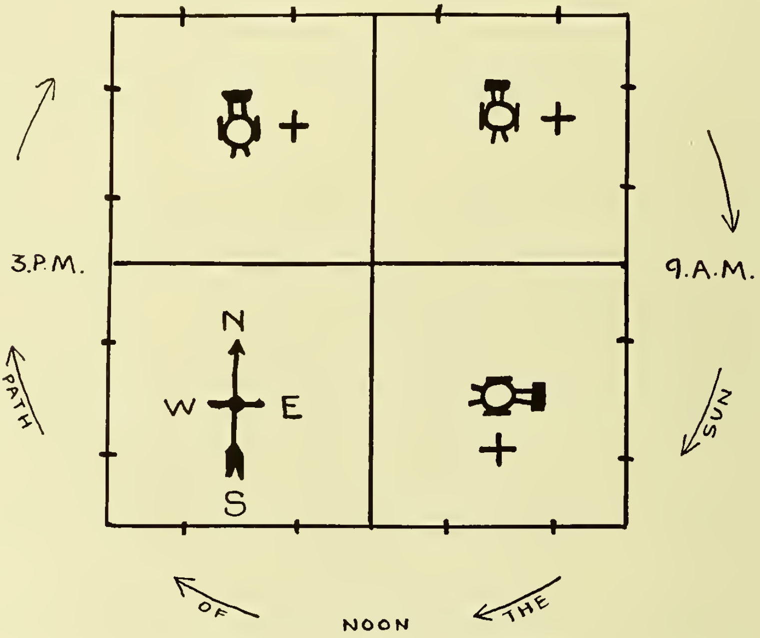


Fig. 279.—Operating room "exposures."

Second.—Avoid flooding the entire room with light, especially the lower portion toward which the operator's gaze is frequently directed; but rather concentrate the light on the field of operation and keep the balance of the room more or less in shadow. Light from a clear sky, falling directly on the work, without shadows is the most desirable.

Third.—Never face a window located to the left of the chair. In case one is present, keep the shade drawn. Neglect of this precaution frequently is productive of great injury to the eyes.

Fourth.—Avoid very large windows which flood the room with too much light. If present, keep a portion of them shaded. An excellent plan in some instances is to equip the operating windows with two separate shades, one at the top and one which will allow pulling up from the bottom. In this way the light may be conveniently regulated at any period of the day.

Fifth.—If possible, admit most of the light for general illumination of the room from a window at the operator's back, thus preventing direct glare into his eyes. The shade for this window should be so arranged that this source of light may be eliminated when so desired. Such a light will be annoying in certain positions at the chair.

Sixth.—Avoid bay windows, which as a rule admit an excess of light and require a great deal of shading.

Seventh.—Make provision in the form of one of the many special artificial light reflectors for use on dark days and whenever needed; also of the electric mouth lamp and mirror and of a magnifying glass for the perfection of the finer details in operative procedures. The use of binocular lenses or loupes is also valuable for this purpose.

The operating window should be low enough to admit horizontal rays of light on the work when needed. Low and medium ranges of light are the most desirable. What has been said with reference to hygiene and lighting arrangement is largely applicable to the students' study room, the classroom, laboratory and clinic. In the dental college where large numbers of students are congregated, special attention to proper ventilation and light should be given. In the clinic, the student may usually manage to avoid unfavorable light by turning the operating chair into another position. Over heated, poorly ventilated classrooms and laboratories lower the efficiency of the student and teacher and are a menace to health.

There are few callings demanding a greater tax on the eyes than the profession of dentistry. Care of the eyes and avoidance of eye-strain should be given constant consideration in the college and in practice. The exactness of vision required and the necessity for long fixation of the focus of the eyes for short distances is very trying and is likely in most instances to demand early artificial assistance. When needed, the services of a competent oculist should be sought and glasses obtained which should be adjusted specially for work at the operating chair, at distances of ten to twelve inches. Additional lenses for reading and other purposes should be provided, if needed.

ASEPSIS IN THE CLINIC AND OPERATING ROOM

Since the introduction of aseptic methods into the practice of surgery, the subject of asepsis in the dental office has gradually become a matter of great importance until today operations are performed in so far as conditions will admit under aseptic precautions in all modern dental offices. The dentist who neglects to sterilize his instruments, linen, dressings, etc., or to take all possible precautions to prevent infection and who does not fully realize the dangers of such neglect is daily rendering himself liable to suit for malpractice.

Dental operations performed in the oral cavity (which is an ideal incubator for germs of all kinds) with unclean hands and instruments, are likely to produce grave infections of the soft tissues with consequent injury, systemic infection and possible death of the patient. Leeuwenhoek, the great Dutch scientist, as early as the eighteenth century said: "More animals live in our mouths than there are people in Holland." The advances in bacteriology and pathology since his time are familiar to the student. The danger of transmission of disease from one patient to another, and the infection of the operator himself under such conditions, is very great. For these reasons, as well as on account of the well-known fact that many diseases are transmissible by way of the clothing, the chair, upholstery, draperies, drinking glasses and similar articles, it is incumbent upon the dentist to take all possible precautions to avoid such occurrences.

Everything in the reception and operating rooms, including the furniture, floor coverings, draperies and other equipment should be in so far as possible of an easily cleansible nature and should receive regular and systematic care and attention. Although it is impossible, under the conditions in which the dentist is working to carry out the methods of aseptic surgery as practiced by the general surgeon, this should be done so far as circumstances will permit after the methods herein described. It is a duty which the dentist owes to his patients as well as to himself.

In addition to the bacteriological and dento-legal aspects of the subject, there is another very important one which should appeal to young men just entering the profession. The intelligent use of aseptic methods will appeal to the average patient and be of great assistance as a practice-builder. Patients of even ordinary intelligence appreciate cleanly methods of operating. If they observe that strict precautions are being taken in the sterilization of hands, instruments and appliances, a psychological effect is produced immediately, the advantage of which readily may be perceived.

This latter argument for the practice of aseptic dentistry is, however, a minor consideration in comparison with the others advanced. In fact, it is unnecessary to mention it at all to the student who has acquired a comprehensive knowledge of bacteriology and the germ theory of disease. He will at once realize the necessity for proper care, for scientific reasons alone.

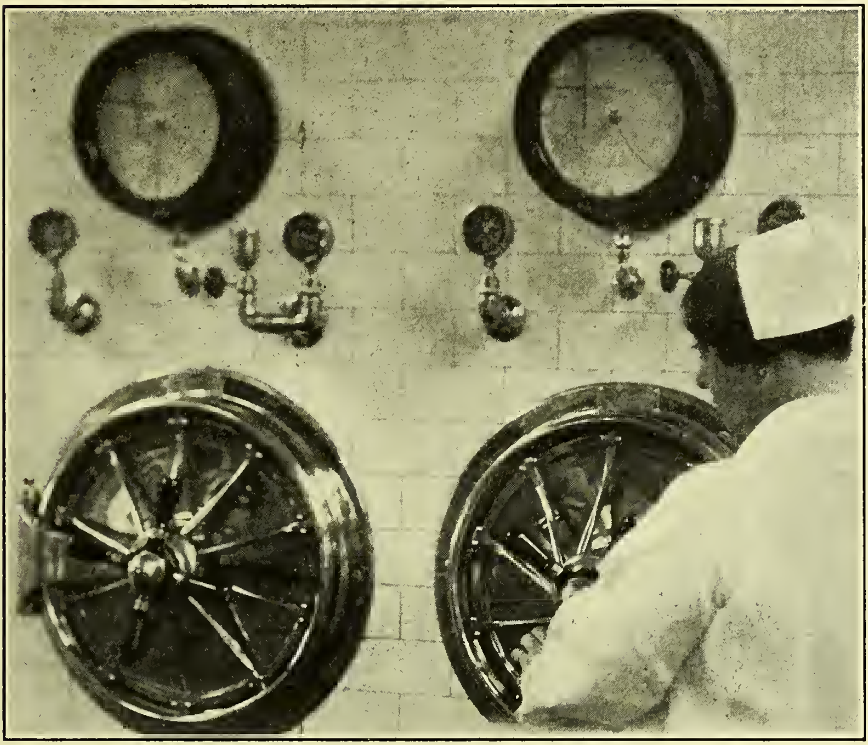


FIG. 280.—Section of the sterilizing plant in a large clinic.

The clinics of all modern dental colleges are now provided with facilities for proper sterilization of instruments and operating appliances, on account of the danger of transmitting disease from patient to patient, or from patient to operator. Fig. 280. The tissues of the mouth are very susceptible to infections. The oral cavity is constantly teeming with micro-organisms, since it offers special inducements for their location and multiplication, such as heat, moisture, food debris and dead epithelial cells. However, these tissues seem to resist inflammatory and infective conditions more than other portions of the body. This was once thought to be due to some antiseptic principle in the saliva, but it is now attributed to the high resistive power and great vitality of the tissues, consequent on their excellent blood supply and nourishment. It is claimed, however, that the saliva does exert a phagocytic action on certain micro-organisms.

Plans for maintaining asepsis in the operating room should include the following considerations:

First.—Care of the operating equipment and appliances.

Second.—Cleanliness of the operator and care of his hands.

Third.—Sterilization of the field of operation.

Fourth.—Sterilization of the instruments and operating accessories.

Equipment and Appliances.—Avoid the use of draperies, floor coverings, wall paper, plush chairs, drawer linings and material in which dust and germs are liable to accumulate. Adopt hardwood, tiled or linoleum-covered floors, which should be washed frequently. Any necessary rugs, draperies and drawer linings should be removable, frequently cleansed and exposed to the sun. The walls should be tinted in a suitable color to prevent eye strain, and frequently cleaned. The chair-seat, arms and back, should be either cane, leather or wood and should receive regular attention.

Select cabinets, tables and drawers of some readily cleansible material. Many modern operators prefer white enamel and glass. All of these should be frequently cleansed.

Change frequently and keep scrupulously clean all necessary table covers, towels and napkins. Some dentists prefer laundered towels and napkins, others selecting specially prepared sanitary paper substitutes. Whichever are used should be sterilized before use.

Pass an antiseptic solution at frequent intervals through the saliva ejector and fountain cuspidor. Boil all saliva tubes, drinking cups and glassware.

The Operator.—He should set an example for cleanliness, through daily baths and frequent changes of linen. He should wear a clean, white operating coat, gown or suit in the operating room at all times. He should avoid long hair and adopt the clean-shaven face. His mouth and teeth should be in a healthy condition and his breath free from odors. His hands, one of his principal assets, should be kept scrupulously clean and his nails close-trimmed, neat and smooth. An orange-wood stick, properly trimmed, will efficiently clean under the nails without roughening their under surfaces or wounding the soft tissues. His hands should be scrubbed with a brush and antiseptic soap in running hot water and then rinsed in alcohol before operating. In special cases of infection, syphilitic patients and surgical operations, they should in addition be immersed in a 1 to 2,000 solution of bichlorid of mercury. The use of sterilized rubber gloves is specially indicated in these cases.

Sterilization of the Field of Operation.—At the beginning of a series of operations, the patient's mouth should first be freed of all calcareous deposits and badly broken-down roots, the teeth thoroughly polished, and diseased soft tissues treated. At the beginning of each "sitting" the use of an antiseptic mouth wash is advisable, or spraying of the mouth with a syringe or De Vilbiss spray bottle containing a good antiseptic, normal saline solution, or 5% alcohol. If the circulation is to be entered, in addition to the above precautions, the part to be operated upon should also be painted with dilute tincture of iodin. Special aseptic precautions should be observed in the handling of the rubber dam and also in root canal therapy. These are discussed in their proper place in subsequent pages.

The Sterilization of Instruments.—Immersion of the instruments in an antiseptic or germicidal solution, such as formalin, 5%; phenol, one to one hundred; or hydronaphthol, 3 to 5% solution, or metaphen 1:500 is advocated by some. Formalin solutions produce rusting of instruments, unless borax in small amount be added. Mercuric chlorid cannot be used for this purpose on account of the same tendency. Immersion in any antiseptic solution primarily for sterilization purposes is a very unreliable method, and consequently, is not recommended. Vaporization by heat of formaldehyde gas, either from formalin solutions or from paraform (solidified formaldehyd) has also been advocated. This is a more valuable method of sterilization than the preceding one, but is now almost abandoned since the introduction of modern steam sterilizers and autoclaves for dentists' use.

After thorough mechanical cleansing with brush, soap and water, the instruments may be boiled in water to which has been added a small amount of sodium hydroxide for fifteen minutes. Then dry thoroughly on a sterile towel. The addition of the sodium salt prevents to some extent the tendency to rusting, although absolute drying is essential. The manufacturers now offer special tablets to be placed in the water in the sterilizer to prevent rusting. The use of a brush-wheel on the engine for the mechanical cleansing of instruments is unsanitary and should not be countenanced. Instruments requiring special precautions, are forceps, broaches, canal reamers, clamps, separators, and lancets, because they are used in or in close contact with the soft tissues, which are more readily susceptible to infection. Rubber dam should be washed in hot water with an antiseptic soap, immersed in an antiseptic solution and then thoroughly dried on a sterile napkin before using. Also, it may be steamed in the sterilizer. The handpiece should be taken apart and cleansed frequently, after which the separate parts may be boiled, oiled and re-assembled. In addition to this, frequently swab with alcohol the part grasped by the hand or remove the sleeve and boil or steam in the sterilizer. Special paper handpiece covers are available, which act as a protective against oral secretions. They may be sterilized before and discarded after use. Recently a formaldehyde sterilizer for handpieces has been introduced. Experiments of Dr. Joseph D. Appleton, reported in the Dental Cosmos, vol. lxvi, August 1924, page 861 indicate that a very effective method of sterilization consists in boiling the handpiece for five minutes in mineral oil at 185°C.

The carborundum or Arkansas stone, chip-blower, engine stones and points and similar adjuncts should be sterilized with the same care as other instruments. Absorbent cotton, cotton rolls, napkins, towels, head-rest covers, table covers, operating gowns and similar accessories should also be sterilized, else the chain of asepsis is broken and contamination of sterilized instruments readily occurs. The operator should avoid, as far as conditions will admit, touching his clothing, hair, face or other unnecessary objects while operating. The cotton-holder should be frequently sterilized and the waste-cotton receiver should be of paper which can be discarded on completion of the operation.

Proper sterilization of dental material demands boiling of instruments for ten minutes or exposure to steam for ten or fifteen minutes. Dry materials, absorbents, linen and similar objects should be steamed thirty minutes. This will destroy all nonsporulating organisms. The spore-bearing germs of tetanus, anthrax or gas bacilli fortunately are not met with in ordinary dental practice. They would not be destroyed by these methods, since they require a longer time. In surgical procedures and in hospitals, the application of steam under pressure at 250°F. is necessary for their destruction. Dry heat at 350° to 400°F. for forty-five minutes or an hour is necessary to destroy most bacteria. The application of these temperatures for the length of time indicated would seriously endanger the temper of dental instruments. Hence, dry air methods of sterilization are impractical for this purpose.

Special sterilizers are now available for dental clinics and private practice for sterilization of instruments by boiling and of dry materials by steaming. In the sterilization of dry materials, they should be wrapped in muslin in special packages and sufficient amounts sterilized for the day's work. After sterilization, care should be observed to avoid contamination of instruments or dry material by exposure or in handling.

CHAPTER IX

EXCLUSION OF MOISTURE FROM THE FIELD OF OPERATION

Exclusion of the secretions of the mouth from the field of operation and the production of absolute dryness are essential to the correct performance of most of the procedures in operative dentistry. This is necessary for the following reasons:

First.—To secure cohesion of gold.

Second.—To perfect the view of cavities.

Third.—To prevent recurrence of decay under fillings.

Fourth.—To diminish the pain of the operation.

Fifth.—To accomplish and maintain sterilization of cavities and root canals.

Sixth.—To avoid discoloration of tooth structure during operations in cavities and canals.

Seventh.—To prevent disintegration of cements and guttapercha.

Eighth.—To prevent dilution and spreading of medicinal agents.

The presence of the slightest trace of moisture destroys the cohesive property of gold, thus interfering with its working qualities. There are very few cavities, the preparation of which should be attempted without the application of the rubber dam. It is well nigh impossible to perform proper cavity preparations in the presence of moisture, which interferes with an adequate view and may result in the leaving of traces of carious matter, and the neglect of other important details. Saliva contains many varieties of micro-organisms, food debris, and material of a fermentable or putrefactive nature, capable of producing caries and discoloration of tooth structure. As a result, if it be allowed access during operations on the teeth, it will in many instances produce discoloration under and around fillings and the undermining of these through a recurrence of decay.

The introduction into or imperfect removal of saliva from root canals is likely to be productive of inflammatory disturbances and septic conditions in the periapical space as well as discoloration of tooth structure after canal operations. In cases of hypersensitive cavities, the removal of all traces of moisture will greatly diminish the pain incident to the operation and make operative procedures less difficult. In the application of medicinal agents, the presence of moisture will greatly reduce the effect desired, through dilution and consequent reduction in the strength of the remedies used. Access of moisture during the introduction of cements and guttaperchas will produce disintegration of these substances. Also it will interfere with the proper adaptation of all filling materials to the walls of cavities. The mucin content of saliva, if allowed to come in contact with the walls of cavities, forms an indistinguishable film which, if allowed to remain, prevents perfect adaptation of filling materials and later offers ready access for germs and moisture. Dryness is essential in amalgam work, since moisture destroys or changes the characteristics imparted to this material by the manufacturer and the dentist.

The two general methods of excluding moisture are:

First.—By use of the rubber dam.

Second.—By use of absorbents.

The introduction of the rubber dam into dentistry by Doctor Sanford C. Barnum of New York City in 1864 resulted in great improvement in the technic of dental operations, and the advancement of dentistry as a profession consequently received a marked impetus. Moisture may be more readily and perfectly excluded with this adjunct than through the use of absorbents. The use of the latter should, as a rule, be confined to operations on the soft tissues of the mouth and to very short or simple procedures on the hard structures. They are occasionally indicated for brief operations on the teeth of timid children, old people, convalescents and similar types, or where for some reason the dam cannot be applied. The rubber dam is in reality a time-saver, since the slightly additional time required for its application is in the majority of cases overbalanced by the elimination of the troubles, inconveniences and seepages of moisture frequently arising during the use of absorbents. Many students seem to have in the beginning a natural timidity in regard to its application and are prone to attempt to dispense with it on that account. Frequent practice in its use will eliminate this feeling and result in efficiency in its application. In cavity preparation and filling operations, the rubber dam, wherever possible, should be used except in very special cases where conditions do not admit of its adjustment or where the operation is of so simple a nature that only a few minutes are required.

USE OF THE RUBBER DAM

Rubber dams are supplied in light, medium and heavy weight, depending on thickness. Light weight dam is easily applied but is more readily torn; while heavy dam is more difficult to handle but is less readily injured. Medium weight usually is preferred because it possesses the advantages of the other two varieties with a minimum of the disadvantages mentioned. Dark colored rubber is usually preferred because of the contrast in color to the teeth, making them easier to guide through the holes punched for their reception. Rubber dam rapidly deteriorates with age. A test of its purity is to stretch it well over the end of the thumb or finger, when, if on relief of the pressure, it returns to its original shape, without tearing or buckling, it is fit to use; otherwise it should be discarded. The dam should be at least six inches in width so that when placed it will extend well beyond the corners of the mouth. For the anterior teeth, it may be cut in oblong form. If the oblong form is used for anterior teeth, it should be at least four inches in length, from its upper to its lower border. For molars the dam should be cut into square form and measure about six inches from upper to lower border; while the size and shape for bicuspids may be intermediate between that for the anteriors and the molars. Usually the square form is better for all cases. It always should be cut large enough to cover the upper lip and chin but should not interfere with the nostrils in breathing. For operations on the six anteriors, at least two teeth mesial and two distal to the tooth to be operated upon should be included as a minimum. As a general rule, for operating on these teeth, the cloth should be extended to the first bicuspid. It is usually bad practice to stop at the cuspid in either jaw on account of its conical shape. For the bicuspids of either side, include one or more of the molars and extend as far forward as the central or lateral, while for molar operations, make the application to include the bicuspids and at least one, or better two teeth, distal to the one operated upon.

Preparation of the Dam.—In general, the holes should be made with the rubber dam punch in about the center of the positions of the teeth to be encircled and should follow the curvature of the arch.

The following conditions will regulate the width of the spaces between the holes:

First.—The spaces between the teeth. Wide interproximal spaces require wide spaces between the holes.

Second.—The height of the gingival festoon. Large festoons or receded gingivae require large spaces.

Third.—The weight of the dam. Light weight rubber requires large spaces.

Fourth.—The size of the teeth. Large teeth demand large spaces.

The average space is two to four millimeters.

The size of the tooth regulates the size of hole to be punched. The hole should not be cut too small. Great care and good judgment are necessary in these respects in order to secure a neat and effective placement. Holes cut too small increase the difficulty of application and are likely to tear. Holes too far apart will produce excess and buckling, while if too close together stretching and seepage of moisture will result. The size of the hole to be punched ranges from ¾ of a millimeter to 3 millimeters, dependent on the size of the particular tooth to be encompassed.

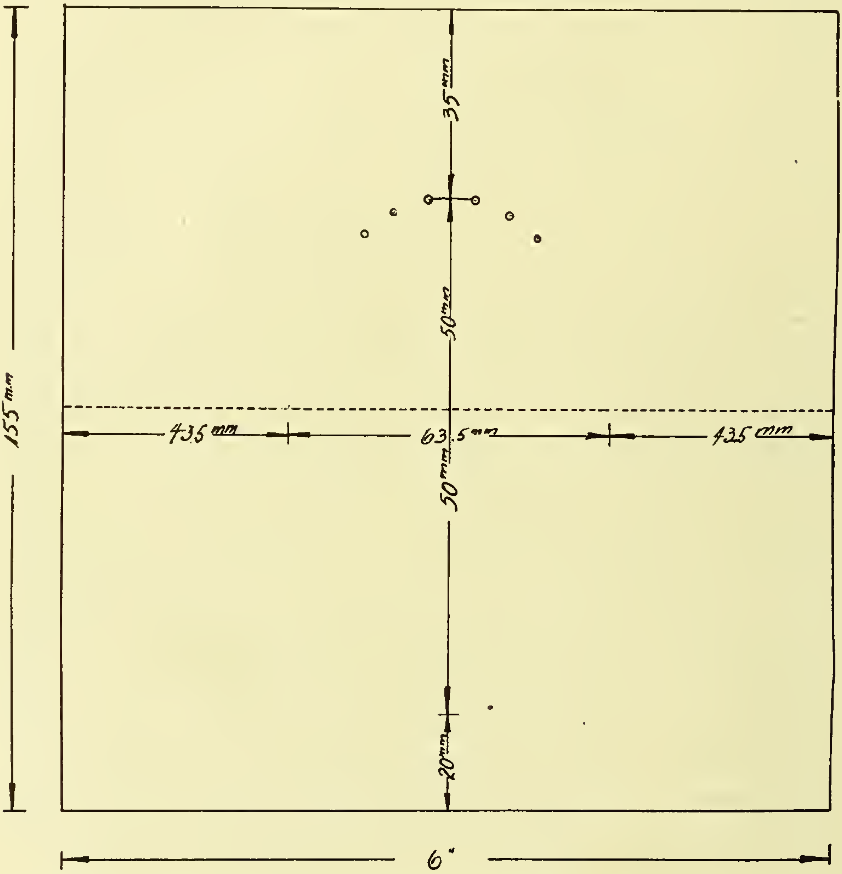


FIG. 281.—Holes punched for the upper six anterior teeth. Figs. 281, 282, 283 and 284 represent diagrammatically the measurements and proper locations of the holes to be punched for the six upper anteriors, the six lower anteriors, the eight upper teeth of the right side and the eight lower teeth of the left side respectively, using dam 6 inches square.

The accompanying illustrations (Figs. 281 to 284) will serve as a guide to the proper preparation of the dam for application to the usual locations. In special cases of irregular placement of teeth, teeth missing from the arch and for gingival third cavities with much recession of the gingiva, the positions of the holes must be varied to meet the requirements. For the latter conditions, where for instance the gingiva is markedly receded, with decay on the buccal surface of the bicuspid extending far to the gingival, the hole for that particular tooth should be punched a little out of the line of the arch, else the stretching of the rubber dam to the gingival to expose the cavity would be likely to pull it away from the tooth mesial or distal to the one affected and produce leakage. As a rule, the holes should be punched slightly farther apart than the total width of the teeth over which the rubber is placed. With

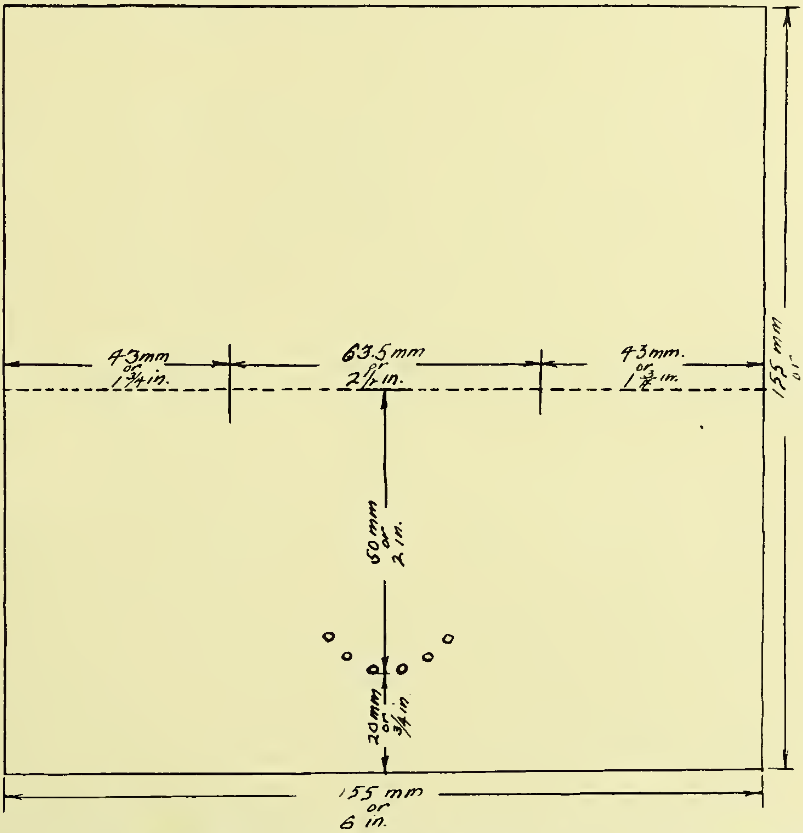


FIG. 282.—Holes punched for the six lower anterior teeth. The average distance (cross mouth) between the third molars is 63.5 millimeters, (2½ inches) which will leave a space of 43 millimeters on each side to the edge of a dam measuring 155 millimeters (6 inches). A space of 35 mm. (1½ inches) should be allowed between the holes for the upper central incisor and the upper edge of the dam, and 20 mm. (¾ inch) for the lowers.

beginners, it is a frequent error to cut the holes too close together, especially for lower anteriors whose necks are broader labiolingually and sometimes also for bicuspids. In any case in which the proximal surfaces of the teeth are very flat, the holes should be cut farther apart than the mesio-distal breadth of the teeth.

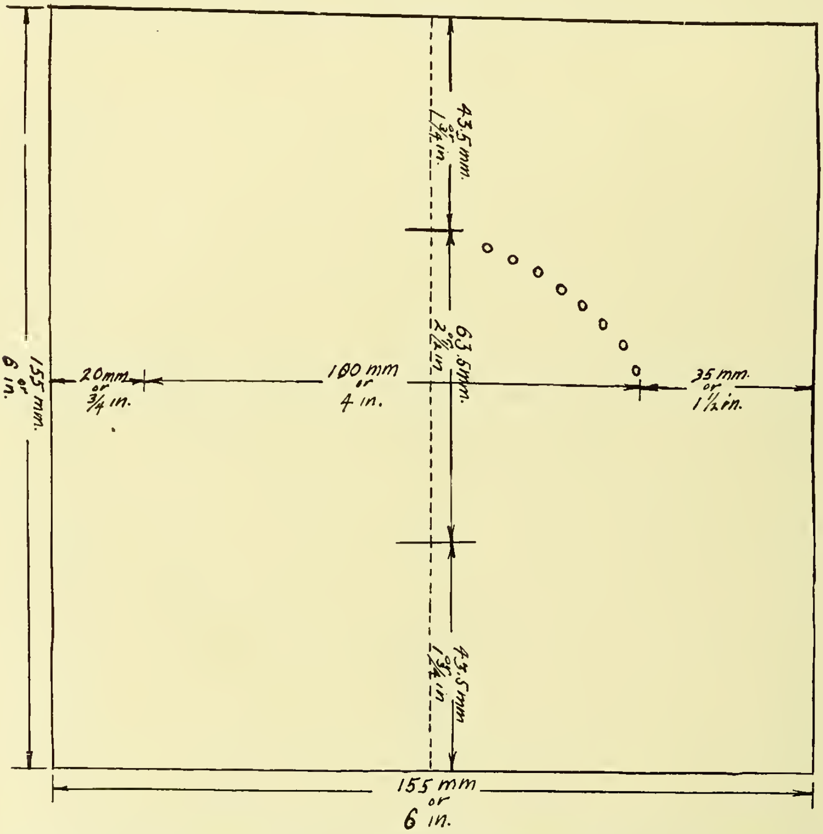


FIG. 283.—Holes punched for all of the teeth of the upper left side. Allowing 35 mm. (1½ inches) from the holes for the upper centrals to the upper edge and 20 mm. from the lower centrals to the lower edge of the dam will leave a space of 100 mm. (4 inches) between these holes respectively, which will be adequate.

Precautions.—The following precautions should be observed before and after removal of the dam.

First.—Remove calculus and glutinous deposits and douche the teeth with warm water or an antiseptic solution before applying the dam.

Second.—Test the contacts and cleanse the interproximal spaces with floss silk before application.

Third.—Remove with excavator or chisel all jagged edges of enamel before application.

Fourth.—Paint the gums with tincture of iodine and wash the dam thoroughly in alcohol before placing it.

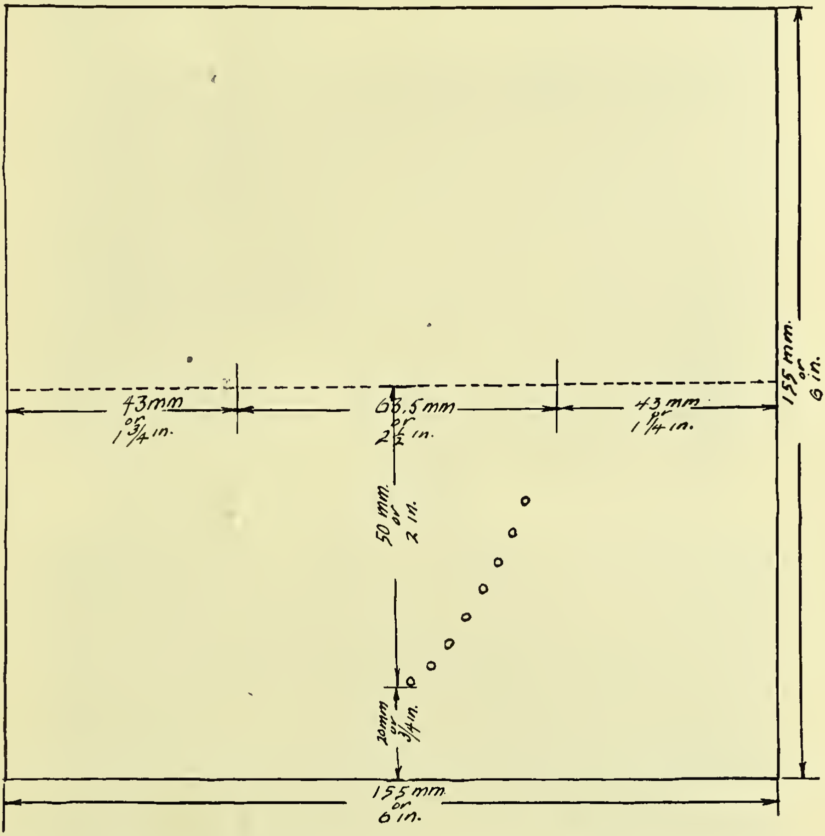


FIG. 284.—Holes punched for lower teeth of left side. The original drawings were to exact scale. The illustrations have been unequally reduced. Dam thus cut and punched is intended for use with the Young frame. Drawings by Dr. J. D. Lombardi.

Fifth.—Swab the teeth and dam with tincture of iodine followed by alcohol and then thoroughly dry with cotton and warm air after it is in position.

Sixth.—Be sure no ligatures or fragments of rubber are left in position after removal.

Seventh.—Flush with warm water or an antiseptic solution and massage the gums after removal of the dam, to restore the circulation.

All of these procedures are desirable to insure easy adaptation of the rubber cloth and to prevent the tendency to injury or infection of the soft tissues.

Clamps and Ligatures.—There are two general methods of making application of the rubber dam, viz., *first*, in cases in which the rubber is to be held in position by ligatures alone; and *second*, where the use of a rubber dam clamp is considered advisable or necessary. In the use of ligatures or clamps, great care should be observed on account of the danger of wounding the gums and pericementum with consequent injury and pain. Many cases of permanent injury and subsequent gingivitis and pericementoclasia are undoubtedly produced by the careless use of these adjuncts. Ligatures usually should not be placed around teeth to which matrices, separators or clamps are to be adjusted. If already

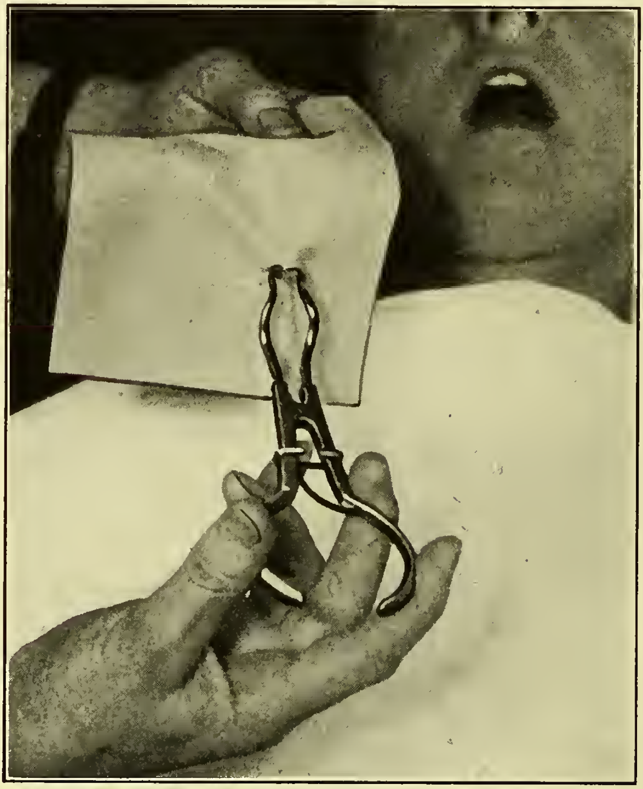


FIG. 285.—First step in applying the rubber dam to the teeth of the upper left side. Holes have been punched to include the teeth from the right central to the left second bicuspid. The clamp has been placed in the proper hole and is being held with the clamp forceps.

in position, they should be removed. Also, the careless use of clamps is likely to damage the enamel, dentin or cementum at the cemento-enamel junction and afford an area for later caries production.

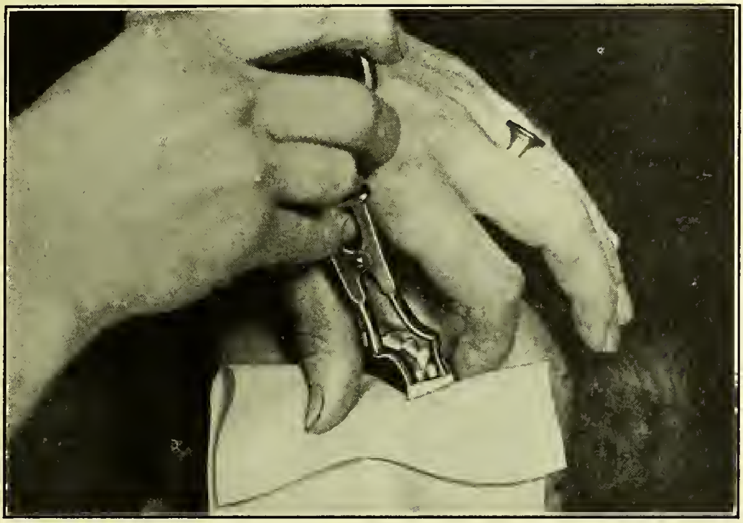


FIG. 286.—The clamp is being applied to the second bicuspid tooth.

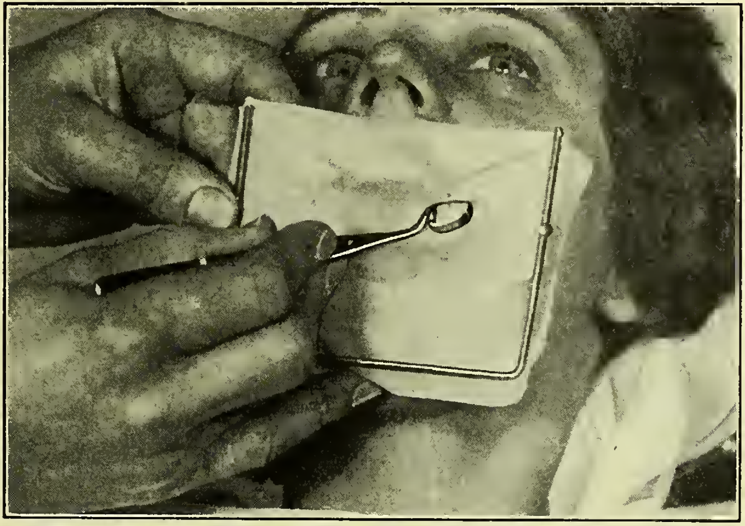


FIG. 287.—The Young frame has been adjusted and the dam is being pulled from off the jaws of the clamp so that it may encircle the neck of the tooth.

For application to anterior teeth, ligatures are used to secure the dam in position. However, it is usually not necessary to ligate all of the teeth included. The fewer ligatures used, the better, on account of the dangers to the gingival tissues incident to their use. For application to bicuspids and molars, a clamp is usually placed on the most distal tooth included in the dam. Where clamps are not used, it is usually best to first place the rubber over the tooth nearest the operator and then proceed with one tooth at a time in regular order until all are

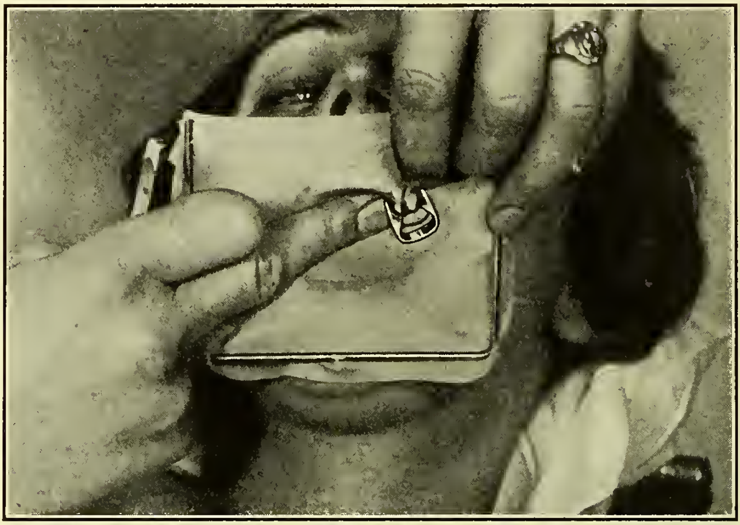


FIG. 288.—The rubber is in position on the second bicuspid and is being adjusted over the first bicuspid.

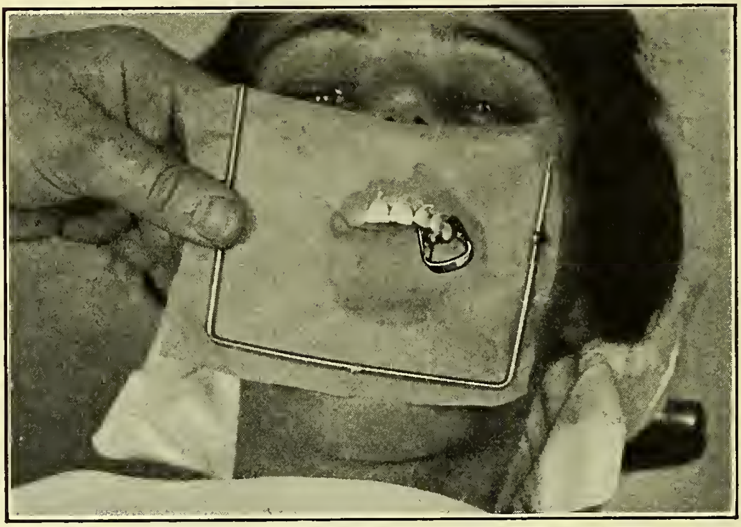


FIG. 289.—Rubber dam adjusted, with clamp and ligatures in place.

included, to avoid obstructing the view. Where a clamp is to be used, it will frequently be better to place the rubber over the wings of the clamp and carry it to position on the farthest tooth away by means of the clamp forceps.

In this method the dam may be wrapped around the handles of the clamp forceps until the clamp is applied, to prevent obstructing the view, when it is released and spread out. After this is accomplished, the rubber should be slipped off of the wings of the clamp, so that it may tightly encircle the neck of the tooth. Then it is slipped over the next tooth mesially and then the next, coming forward until all are included, a ligature being placed on the last tooth encircled to securely hold the dam in position. In both methods only a sufficient number of ligatures should be used to avoid leakage. Figs. 285 to 290.

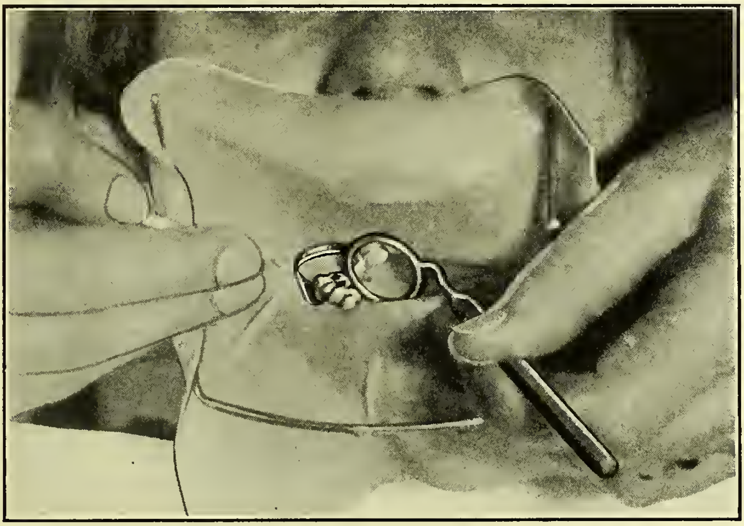


Fig. 290.—Rubber dam being adjusted to lower right side. The clamp and Young frame are in position.

Rubber Dam Grasps.—In carrying the rubber to position over individual teeth, the method of grasping it is important to secure the best results. This will vary, depending on the operating position and the location of the operation. The side of the rubber to be applied next to the gingival is called the gingival side while that which faces the occlusal surface of the teeth is the occlusal side. In some instances, depending on the position, the thumbs should grasp the occlusal side of the rubber immediately over the hole, with the thumb nails in contact, while the fore-finger of each hand grasps the gingival side. In other instances the occlusal side of the hole is grasped by the fore-fingers with the nails in contact over the hole and the thumbs on the gingival side of the cloth, this position being the reverse of the preceding one. In other positions it will be more convenient to grasp the occlusal side of the hole with the thumb of one hand and the fore-finger of the other.

In either instance, the occlusal side should be grasped with the nails of fingers or thumbs in contact immediately over the hole, when the dam should then be stretched, one edge of the hole caught over one side of the tooth to be encircled, mesial or distal, then stretched over the other side, when it should be forced into position with a see-sawing motion until the nails of the fingers or thumbs, as the case may be, hold the rubber closely against the gingiva, on both labial (or buccal) and lingual sides. This is the first part of the movement. Now, holding the occlusal side of the rubber hard against the labial and lingual sides of the tooth, slightly release the hold of fingers or thumbs on the gingival side, when the rubber will usually be felt to draw tightly around the neck of the tooth and also around the ends of the fingers or thumbs still holding it. The fingers or thumbs should now be given a slight shaking motion before releasing the pressure on the tooth, which will release the hold of the rubber on them and allow it to draw more tightly around the neck of the tooth. The hold on the rubber should now be released, when if the movements are properly performed, the dam will be in position with the margins of the holes pointing gingivally as they should be, thus forming a valve-like arrangement against leakage. Much care should be exercised to see that the hold of the rubber dam on fingers or thumbs on the occlusal side is released before withdrawing them, else the rubber is likely to be pulled out of position on withdrawal of the pressure.

Special Procedures.—In case of tender gums, the application of novocaine solution, oil of cloves or other topical anesthetic will help to relieve pain. In some cases, the application of waxed floss silk ligatures is necessary to force the dam and hold it to position. The use of a small burnisher or of dressing pliers with or without the ligature will also be of assistance in turning the edges of the holes root-wise to insure a saliva-tight joint. Ligatures should be very carefully applied and only when necessary, on account of the danger of injury to the soft tissues. Owing to the deep curvature of the free gingiva on proximal surfaces of anterior teeth, special care should be taken to avoid pulling the ligature too tightly on these teeth and damaging interproximal gum tissues and the attachment of the pericemental membrane. Fig. 291 fully illustrates these dangers in applying the ligature on central, lateral and cuspid. The gingival line is straighter on bicuspids and molars, with a consequent lessened tendency to injury from this cause. Usually the application of clamps is dispensed with on the anterior teeth, while their use is valuable on molars and occasionally on bicuspids.

In applying the ligature, it should be gently insinuated into the proximal space, avoiding suddenly or forcibly snapping it past the contact point and on to the sensitive gum tissue. Pass a loop around the tooth and bring the ends together. While holding them in the left hand and before drawing tightly, insert a smooth burnisher (Fig. 292) or the beaks of a pair of dressing pliers beneath the loop on the lingual side, carry it below the gingival border and apply traction on the ends of the ligature. This will carry the loop to position above the linguo-gingival ridge on anteriors, or to the cervix on posteriors, force the edges of the dam more securely gingivally and prevent them from slipping out of position. Now tie the ligature with the first half of a surgeon's knot (Fig. 293) and complete the tie with a single knot, when the ends may be cut close to the knot with a pair of short, blunt-pointed scissors or a ligature cutter. Fig. 294.

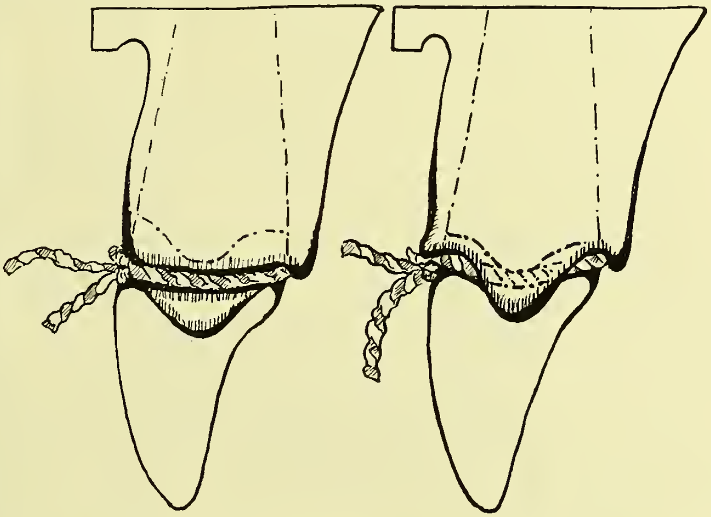


Fig. 291.—Danger of injury to the gums from careless application of ligatures on anterior teeth.

With thick-neck teeth, in difficult cases and where it is especially desirable to prevent slipping of the ligature, a double ligation may be made. For this purpose, reverse the first passage of the loop, making a single or surgeon's knot on the lingual surface, draw the ends through the interproximal spaces again and tie a surgeon's knot on the labial side, thus making a double ligature or Wedelstaedt tie. Fig. 295.

The soft tissues of the mouth of some individuals are extremely sensitive to touch. Certain patients of this type will manifest a marked dislike to the use of the dam, many of them presenting symptoms of gagging, nausea or spasmodic coughing. In these cases, tact and encouragement are necessary. A wash or spray of camphor water or, in extreme cases, swabbing the parts with tincture of camphor will be of assistance. Topical anesthetics are also available for this purpose.

A condition simulating approaching syncope sometimes arises from the application of the dam. In this case, instruct the patient to breathe through the nose. Often this will relieve the situation. If fainting is imminent, remove the dam, open the window, place the patient in the horizontal position,

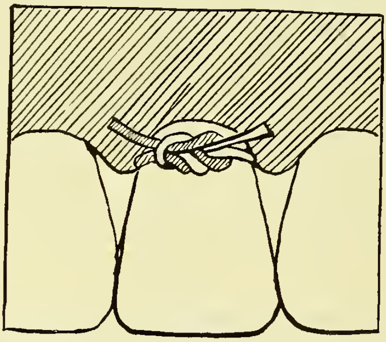
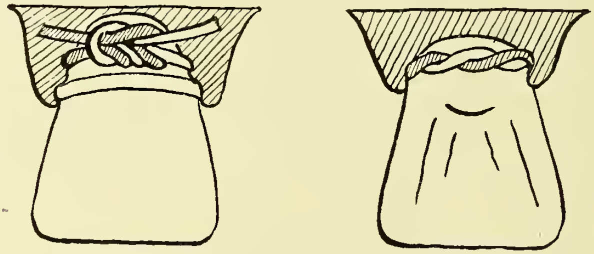


Fig. 293.—Surgeon's knot.



Labial

Lingual

Fig. 295.—Double ligature or Wedelstaedt tie

Fig. 292.—Burnisher.

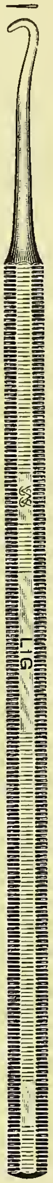


Fig. 294.—Ligature cutter.

or anesthetic-narcotic position, apply cold water to the face, loosen tight clothing and massage the wrists. If the patient be still conscious and it is deemed necessary, administer in water, one-half to one dram aromatic spirits ammonia, or one to two drams camphor water. In dangerous cases of syncope from this or any other cause, with the patient unconscious, administer one-sixtieth to one-thirtieth grain strychnin sulphate, or one-one hundred-fiftieth grain nitro-glycerine hypodermically; or break a five-minim ampule of amyl nitrite in a napkin and apply carefully to the nostrils.

Difficult Cases.—The following procedures may be resorted to in adjusting the dam to close spaces and in difficult cases:

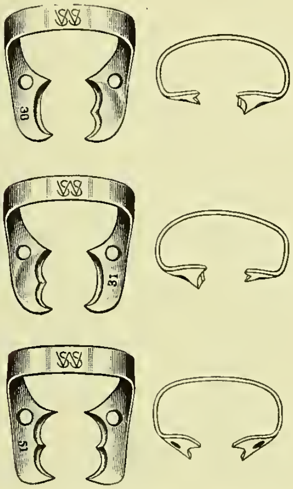


FIG. 296.—Rubber dam clamps, Nos. 30 and 31 for upper molars (right and left) and 51 universal lower molar.

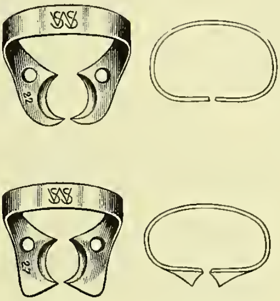


FIG. 297.—Rubber dam clamps, Nos. 22 and 27 for bicuspids.

First.—Slight separation of the teeth by a thin spatula or a wedge to assist in forcing the dam or ligature to position.

Second.—Application of vaseline to the teeth included in the dam or to the holes of the dam to cause it to move into position more readily.

Third.—Application of a topical anesthetic, clove oil or novocain, to the gums for relief of pain.

Fourth.—First swab the teeth with alcohol to remove mucous deposits which have a tendency to cause slipping of the dam from position.

Fifth.—Use of a small section of rubber tubing or a small bead strung on to the ligature; or of cotton, or knots tied into the ligature and applied on the lingual aspect of the teeth ligated, to prevent the rubber from slipping from position.

Use of Clamps.—A sufficient number and variety of rubber dam clamps (Figs. 296 and 297) should always be at hand to insure the selection of one which can be securely applied to teeth of various sizes and shapes. An ill-fitting clamp is a nuisance and endangers the operation throughout on account of its tendency to slip off, injure the tooth and soft tissues and cause leakage. Two classes of teeth are especially difficult to clamp, namely, *first*, bell-crowned teeth, on account of the tendency of the clamp to slide toward the gum, and *second*, thick-neck, conical and peg-shaped teeth, on which the tendency is to slip off the tooth. A well-fitting clamp, properly applied should obviate these tendencies. The Hatch cervical clamp (Figs. 298 and 299) is especially designed for use in cases of gingival third or Class V cavities. In these cases, the decay has frequently extended well beyond the free gingiva and thus prohibits the use of a ligature or ordinary form of clamp. In some cases, it will be advisable to anesthetize the gum before application of the cervical clamp; in others of extensive decay, extending far rootwise, it will be better to partially prepare the cavity, insert a temporary filling of guttapercha to force away the gum and attempt the application of the clamp at a subsequent visit. In either case the dam should be applied in the usual way, no ligature being used on the tooth to be clamped. The rubber is then forced above the gingival margin of the

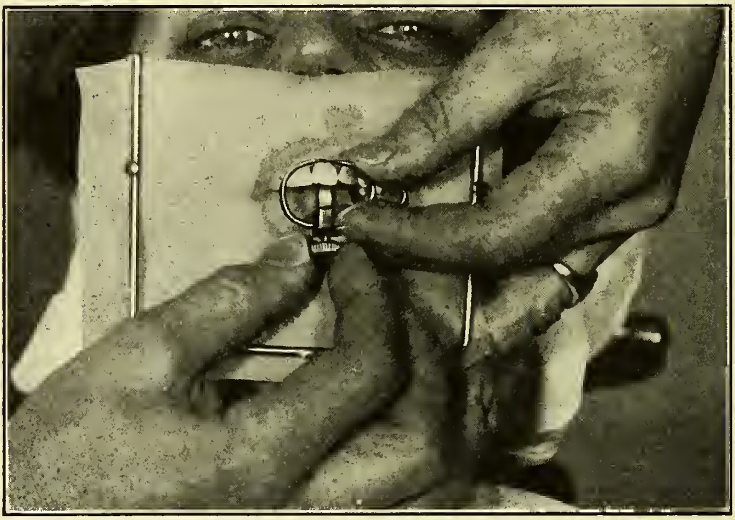


Fig. 298.—Adjusting the Hatch cervical clamp.

cavity by means of the beaks of the clamp, the appliance then being tightened into position by means of the set-screw, thus exposing the operating field and protecting it from moisture. Before applying it the clamp should be so adjusted that only one or two turns of the set-screw will be necessary to tighten it into place. Fig. 300.

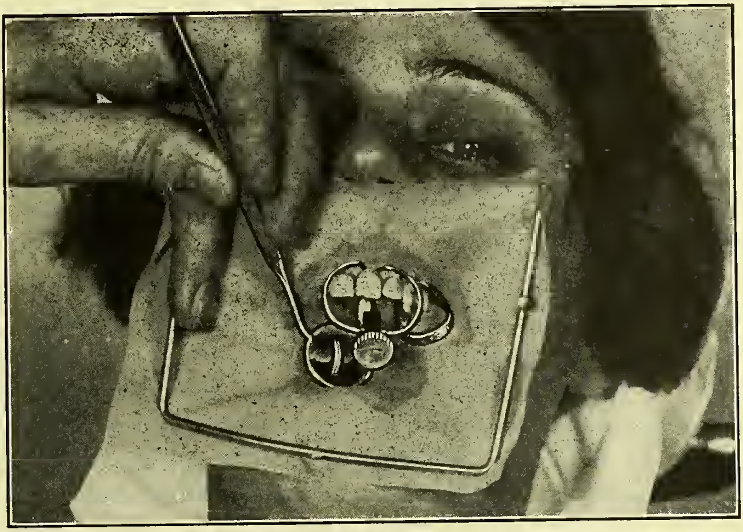


FIG. 299.—Hatch cervical clamp adjusted.

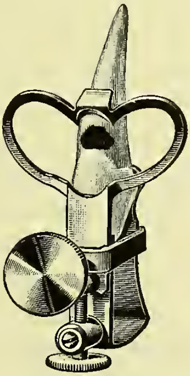


FIG. 300.—Ivory cervical clamp.

Rubber Dam Frame.—The Young rubber dam frame is the best appliance yet devised for holding the dam in position after clamps and ligatures are adjusted. It is readily sterilized, easily adjusted and dispenses with the necessity for rubber dam weights and the application of napkins and other absorbents between dam and cheek as protective devices. The ordinary rubber dam holder with its rubber bridle is a most unsanitary appliance, since it cannot be properly cleansed or sterilized. The Young frame (Fig. 299) owing to its movability while in position may appear awkward to the beginner, but this slight disadvantage is quickly overcome with use. It, together with clamps and other accessories, should be sterilized by boiling before use.

Removal of Ligatures and Rubber Dam.—When the operation is completed, great care should be observed in the removal of clamps, ligatures and rubber cloth. All clamps should first be gently removed, when ligatures should then be cut on the labial or buccal side with a sharp knife or lancet. They may then be gently withdrawn with a pair of dressing pliers, avoiding wounding the gingiva during withdrawal. In case an amalgam filling has just been placed, special care should be exercised in withdrawing ligatures, else they may damage the still plastic filling material. In these cases, it will be well to sever the ligature on the lingual side also and then carefully withdraw it in two separate sections. In removing the dam it should first be stretched well to the labial or buccal side and each septum going between the teeth should be cut with a small pair of blunt-end scissors, when it may then be readily and quickly released and the saliva be removed from the patient's cheek and chin with a dry towel. A thorough examination should now be made to see that no fragments of ligature or rubber have been left in position, since they are capable of producing great injury to the soft tissues if not removed. Following this, the measures previously mentioned for restoration of the circulation in the gingiva and prevention of infection should be resorted to.

Use of Absorbents.—For short operations, in cases not admitting of the use of rubber dam and occasionally with children, the use of absorbents, such as cotton rolls or mouth-napkins may be necessary or advisable. Cotton rolls are supplied in six-inch and one-half inch lengths, and in diameters of five-sixteenths, three-eighths, one-half and five-eighths of an inch. The smallest size is designated as number one, the next largest as number two, the next number three, while the largest is number four. Mouth-napkins are usually six or seven inches square and supplied in sterile packages.

These adjuncts are utilized with two general purposes in view, namely, *first*, to temporarily occlude the ducts of the salivary glands and dam back the salivary flow and, *second*, to absorb the moisture present. The successful use of absorbents depends largely on the accomplishment of the first consideration mentioned. If they are properly placed and held in position with cotton-roll clamps, the operating field may often be kept dry for a considerable period of time. Cotton rolls are usually most efficient for this purpose, the size of roll to be used being dependent on the size of the mouth of the patient and the space which is to receive it. In operations on upper teeth, one or more rolls should be placed in position to the buccal side and another to the lingual side of the teeth and securely tightened in place with a cotton roll clamp. To occlude the duct of the parotid gland, the rolls should be of sufficient size to fill the space between the cheek and the buccal surfaces of the molars and produce pressure over the duct. Moisture may be fairly well excluded from all of the teeth of the upper jaw in this manner by placing rolls over the parotid duct of both sides, under the lip, over the anterior teeth and also to the lingual sides of anteriors and posteriors. The use of cotton-roll clamps is necessary to hold the rolls tightly in place.

For operations on lower teeth, it is first important to occlude the ducts of the sublingual and sub-maxillary glands by placing rolls of sufficient size to produce pressure over these glands, under the tongue in the floor of the mouth. Next, rolls should be placed to the buccal and labial sides and all should be secured with cotton-roll clamps. For prolonging dryness in this field, additional rolls may be used above, to stop the flow from the parotids. However, it will seldom be necessary to resort to so extensive a packing of the oral cavity as mentioned, since the operation is usually of short duration and confined to one side, or to the front of the mouth in either jaw. It should be remembered, though, that success with absorbents depends primarily in stopping the salivary flow at its source and not merely in absorbing moisture present. For very brief operations consisting of doing one simple thing and requiring only a movement or two, a mouth-napkin will be sufficient. In the use of both napkins and cotton rolls, the surfaces of the teeth included in the application are of course dried by swabbing with pledgets of absorbent cotton and with warm air after the saliva has been excluded. The saliva ejector, which drains the secretions into the fountain cuspidor is of great assistance to prevent accumulation of saliva in the mouth during the use of both rubber dam and absorbents. The internal administration of atropin sulphate, $1/150$ gr. for adults, a short time preceding the operation will often diminish the salivary flow. In addition to napkins and cotton rolls, other types of absorbents, such as cottonoid, lintine, bibulous paper, absorbent cotton, absorbent pledgets and absorbent paper points (for drying root canals) may be mentioned.

CHAPTER X

PREPARATION OF CAVITIES—PATHOLOGY AND CLINICAL FEATURES OF DENTAL CARIES WITH REFERENCE TO CAVITY PREPARATION

By "preparation of cavities" is meant those procedures incident to the removal of decay and the shaping of cavities in such a manner that, when filled, the teeth in so far as possible will be restored to their original form and strength and be relatively immune from recurrence of decay in the same locality.

Before beginning the study of cavity preparation it is necessary that the student have a comprehensive knowledge of the causes, pathology and clinical features of dental caries, since this morbid condition is the immediate cause of the production of cavities in teeth requiring the filling operation. Also, it is highly important for him to be thoroughly familiar with the form, structure and functions of the teeth on which he is to operate. This latter knowledge he should have acquired previously in his studies in Dental Anatomy and Histology, consequently, these subjects will not be reviewed here. However, special phases of them will be discussed in their proper place as the theory and technic of cavity preparation is unfolded. Many aspects of the causes and pathology of dental caries were presented in the chapters on Preventive Dentistry, to which the student is referred. Additional data is herewith given in connection with the following description of the clinical aspects and progress of caries of the teeth. Matters of this nature should be confined to special text-books on the subject and no attempt is made in this work to enter into an exhaustive discussion of them. However, to meet the needs of teachers and students of operative dentistry, it has been deemed advisable to dwell especially on those phases of the subject which have a definite practical bearing on the problems of prevention and of restorative procedure.

CLINICAL HISTORY OF DENTAL CARIES

In the chapters on "Prevention" it was found that the factors concerned in the production of dental caries are exciting and predisposing as well as local and systemic in character. Also it was emphasized that if the predisposing and systemic causes be largely or entirely absent, the exciting and local causes may be to quite a degree held in abeyance through intelligent, systematic and regular local hygienic means. Also it was found that the carious process is a double decomposition of tooth structure resulting from fermentation and putrefaction. The first or fermentative phase consists of a dissolution of the inorganic salts of the enamel and dentin through the action of lactic and other organic acids which result from the fermentation of carbohydrates by aciduric micro-organisms, principally bacillus acidophilus. The second or putrefactive phase results in a destruction of the organic, protein constituents of the dentin through the action of putrefactive bacteria. If the claims of Bödecker, Gies and others, that the enamel contains small percentages of protein material, are allowed (which claims are not yet entirely accepted by some investigators), the putrefactive process would also be concerned in caries of enamel.

Inception of Caries.—Dental caries affects all ages and conditions of mankind. However, its ravages are most frequently seen and are usually more pronounced in the adolescent periods of life. From eight to twenty-five years of age are the periods of greatest susceptibility and if the patient can be safely carried through this period of stress and at the same time be taught efficient methods of oral hygiene, the denture can with reasonable care on the part of the dentist, usually be saved for the balance of its natural existence, certainly as far as loss of teeth from caries is concerned.

Poor hygiene, abundance of gluten in the diet, and excess of glycogen in the saliva in youth are often responsible for greater susceptibility at this period. Very filthy dentures sometimes escape the ravages of decay owing to the occurrence of putrefactive processes incident to excess protein in the diet. Putrefaction is an alkaline process which would interfere with the localization and activity of the aciduric types of organisms concerned in the fermentative process. A similar condition is noted in cases of long continued putrefaction of the pulp, where the progress of caries in the affected tooth is often markedly retarded. The same occurrence is noted in marked cases of pericementoclasia with pus formation. Dental caries rarely attacks dentures affected with this latter type of disturbance, owing to the alkalinity of the by-products formed in these conditions. Also in pyorrhea, excessive alkalinity of the saliva and its increased calcium content seems to have an acid neutralizing effect, thus militating against caries production. Caries is sometimes secondary to abrasion or erosion, being more rarely found in the latter condition, the usual highly polished, eburnated surface here probably not affording a favorable location for food and formation of the bacterial plaque.

The history of dental caries extends back as far as semi-civilization—certainly to the time cooked cereals began to be included in the dietary of man, originally a carnivorous animal. Races living on an exclusive meat diet have not been affected to any extent. Eskimo tribes, South Sea Islanders, and other aborigines in many parts of the world which have existed on exclusive meat diets have been moderately free, one tribe of Eskimos exhibiting only 3% caries, others entire absence of this condition. As soon as a mixed diet is adopted and civilization creeps in, the incidence of caries has in a number of reported instances been increased 30 to 40%. Interesting findings have been reported by Doctor L. M. Waugh and others which confirm these statements. Immunity and susceptibility to dental caries in civilized races is due largely to methods of oral hygiene, systemic conditions affecting the structure of the teeth during the formative period, character of the oral fluids in which the teeth are bathed (alkalinity and calcium-content), type of diet, regularity of the arches, form of the teeth and character of mastication. During the life of an individual, there may be periods of increased susceptibility or relative immunity. Periods of immunity or susceptibility may be due to (1) a temporary lack of hygiene; (2) changes in systemic conditions which affect the constituents of the oral fluids, thus supplying or depriving them of some unknown element, nutritive or inhibitive to germs or supplying them with acid neutralizing substances; or (3) to changes in the components of the dietary. According to Burchard[1] the periods of greatest susceptibility are from 5 to 8 years of age; 12 to 20; 30 to 35; 40 to 50; 60 to 65; and the age of senility. Caries, however, is frequently found rampant in the deciduous teeth; most often, though, it is observed in adolescence. In old age, with receded gingivae, gingival third cavities are frequently seen. Caries originates largely in the winter and early spring and its inception is much rarer in the summer months. This is probably due to change of diet, environment and out-door living in the latter periods of the year.

Caries is usually observed in the following localities in the order of frequency mentioned, viz. (1) in defective pits and fissures on occlusal, buccal and lingual surfaces, (2) on proximal surfaces with open or flat contacts and (3) on the gingival third of labial and buccal surfaces. These areas offer the most favorable localities for the deposition and retention of carbohydrate food masses and the formation of the bacterial plaque. Cavities in other localities are exceedingly rare. Remnants of Nasmyth's membrane act as a breeding ground for bacteria. Fig. 301. Wherever food debris is more readily retained, caries is likely to begin. Decay most frequently has its inception on protected areas, as in pits and fissures and proximal surfaces. It is not often found on surfaces exposed to mastication and the excursions of food masses or on those subjected to the cleansing action of the lips, cheeks, tongue and salivary washings. Dentures with regularly aligned arches and relatively perfect types of occlusion are usually less susceptible to caries. Teeth rotated in the arch are sometimes subject to proximal decay in unusual situations, the cavity occurring on the surface in contact with the approximating tooth.

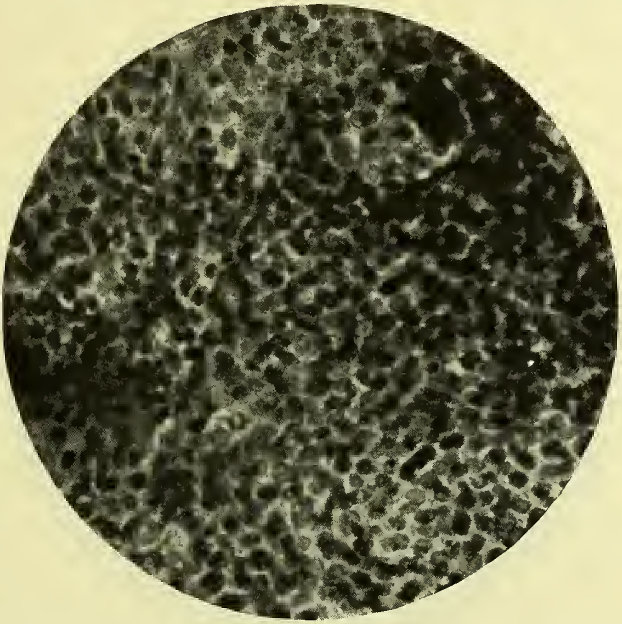


Fig. 301.—Nasmyth's membrane. (Courtesy of Dr. Samuel Wood Chase and "The Anatomical Record.")

In the absence of the principal causes and favoring conditions for their action, caries would not occur; consequently, it is highly important that the student closely study the local clinical conditions producing decay in order that his cavities may be so prepared and his restorative operations so constructed that its recurrence may in so far as possible be prevented. In the early stages of superficial caries of the enamel, the condition may often escape detection, even on exposed surfaces, when moist or bathed in saliva. If dried, the area will frequently appear as a whitish or chalky, slightly eroded area. As the condition progresses, pigmentation usually occurs, the color ranging from light yellow to light brown, reddish brown, dark brown, grey and even black. Discolorations are due to chromogenic bacteria, such as the bacillus fuscans, and also to the formation of iron salts incident to putrefactive changes. In the early stages, the affected area may appear as an opaque white or slightly discolored spot or there may be several minute openings in a generally decalcified locus. These usually will later coalesce. The extraction of an approximating tooth will frequently stop or retard the further progress of proximal caries, since food debris is no longer retained in the affected area. A similar retardation may occur from some immunizing influence, such as the application of stricter prophylactic procedures, or a change of diet affecting the constituents of the saliva. The rapidity of progress of the condition is also frequently retarded in large, superficial cavities exposed to the friction of food masses and the flushing action of the saliva. The term "arrested caries" is used to designate these types. Secondary dentin and areas presenting tubular calcification decay less rapidly, while pulpless teeth decay more rapidly.

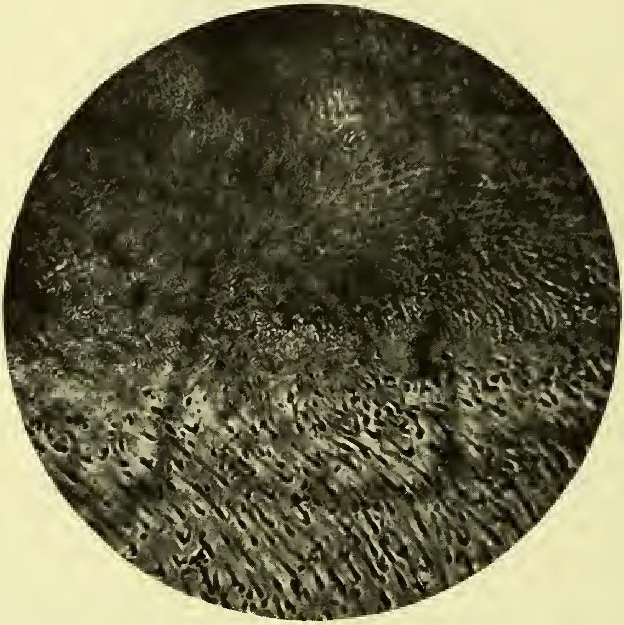


FIG. 302.—Dento-enamel junction, showing the dentinal tubules below and the enamel prisms above in longitudinal, transverse and oblique sections. High power. (Courtesy of Dr. John B. Stein.)

Thick, mucinous salivas favor the adhesion of food masses and bacteria and stimulate caries production. Excess of soft pappy foods, particularly wheat cereals containing large amounts of gluten, act in a like manner. Fatty foods mixed with saliva and retained in position have a retarding influence owing to their alkalinity. Rapidity of decay depends on intensity of action of the exciting causes, the environment and location, the shape of the tooth, structural defects, regularity of the arches and the care given the mouth. Enamel destruction is the longest phase, while penetration of the interglobular spaces and the granular layers of the dentin is the most rapid. Figs. 302, 303, 304 and 305. The size of the orifice of the cavity is often no guide as to the depth of penetration, the enamel often remaining partially intact over areas of deep and widespread caries of dentin. In pits and fissures, the tendency frequently is for the carious process to penetrate deeply ("penetrating or infiltrating caries") before extensive enamel destruction occurs; while "spreading" or "extension" caries is more often found on smooth surfaces. Fig. 306. However, in proximal caries on bicuspids and molars the dentin underlying the marginal ridge may be deeply undermined before the overlying enamel is broken down. In carious cavities the bacterial plaque lines

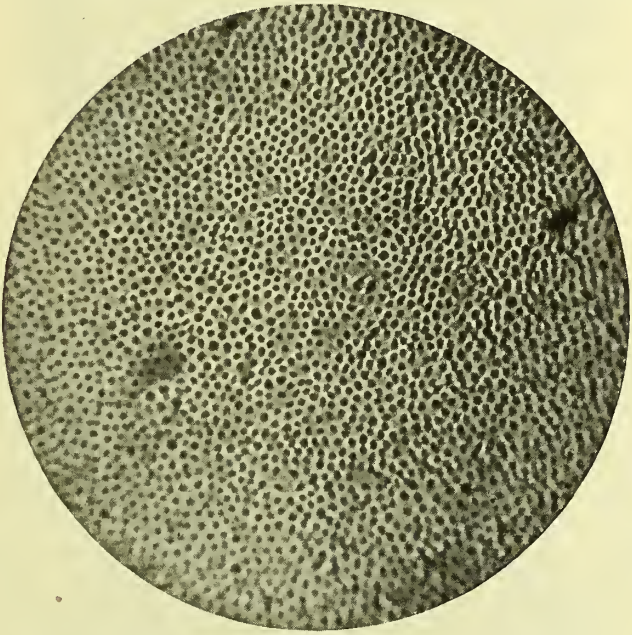


Fig. 303.—Dentinal tubules seen from the pulp chamber. Low power. (Courtesy of Dr. John B. Stein.)

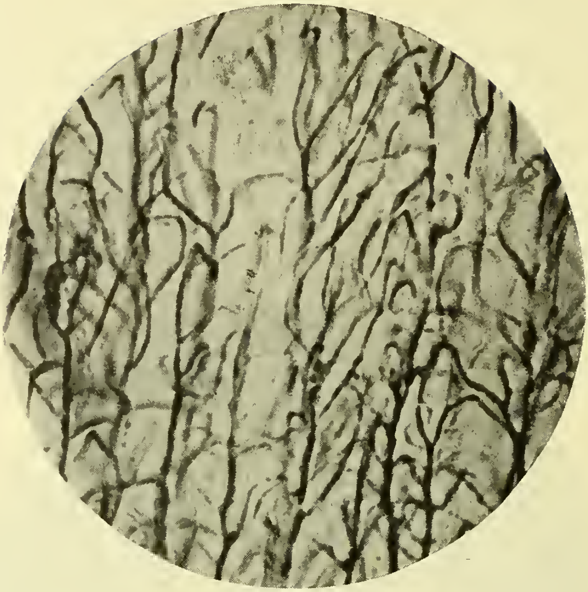


FIG. 304.—Dentinal tubules, showing lateral anastomotic branches. (Courtesy of Dr. Harold K. Box.)

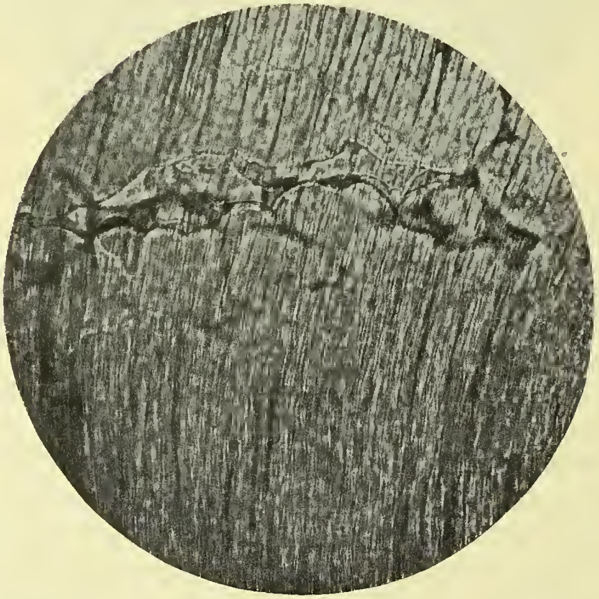


FIG. 305.—Dentin of crown showing interglobular spaces. (Courtesy of Dr. John B. Stein.)

the cavity walls as a thin film, over which is a layer of food debris. The acid-forming micro-organisms appropriate carbohydrate food from this overlying layer and form lactic acid which is deposited under the plaque. Fig. 307.

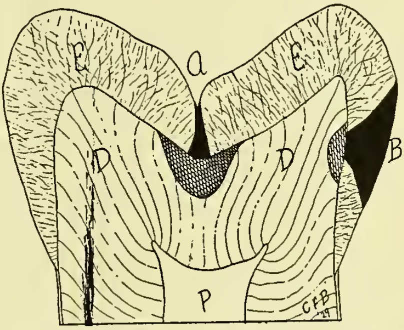


FIG. 306.—Sketch showing penetration of caries in an occlusal fissure at A and on a proximal surface at B. (Courtesy of Dr. Charles F. Bödecker and the Publisher of "Dental Items of Interest.")

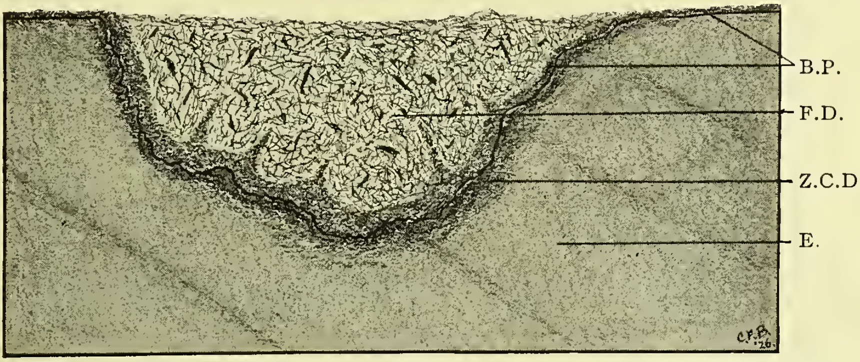


FIG. 307.—Sketch showing initial caries of enamel. B.P., bacterial plaque lining cavity. F.D., food debris. Z.C.D. zone of carious degeneration. E. enamel. (Courtesy of Dr. Charles F. Bödecker and "The Dental Cosmos.")

Hardness and Softness of Teeth.—Much has been written about variations in the hardness of the teeth, their resistance to cutting instruments and to the action of the acids of decay. Difference in the hardness and cutting consistence of specimens of enamel is at present attributed to variations in its histologic structure and not to its chemical content. Differences in the size and extent of the interglobular spaces and the granular layers would account for some variations in the resistance of the dentin to cutting instruments and rapidity of decay. G. V. Black reported a difference of only 4.35% in calcium content of various specimens of dentin, while differences in this respect from age were only 2.30%. He found that differences in the cutting consistence of dentin were almost negligible.

Effect of Acids on Tooth Structure.—In an important and exhaustive research on the effects of acid on tooth tissue published by Thurlow and Bunzell in the Dental Cosmos, Vol. LXIX, January 1927, the authors made an interesting and important report. They found that (1) There is no distinct difference between the resistance to acid attack of the enamel and roots of teeth with so-called hard and soft enamel.

2. The enamel is attacked more rapidly by acids than roots, due to its greater percentage of inorganic matter.

3. That the enamel from all the teeth is dissolved in roughly the same amount.

4. The ease with which various acids attack enamel does not depend on the normality of the solution.

5. The organic acids act for the most part more rapidly in normal concentration than in 5N or 10N concentration.

6. The effect of different acids on enamel does not depend on the hydrogen-ion concentration of the solution.

7. The rate of attack by acids having a pH value corresponding to the most acid salivas is very slow.

8. Acid salivas play no role in any direct attack on either enamel or roots of teeth.

Statistical Findings.—Dr. Thaddeus P. Hyatt has contributed over a period of many years very valuable statistics with reference to the incidence of caries of the teeth. The accompanying graphs were made especially for this work under his supervision and that of Dr. Alfred J. Lotka, statistician of the Metropolitan Life Insurance Company. The figures at the left in these graphs indicate the possible number of cavities there might be present in 12,753 persons. For example take the occlusal surface in an upper first molar tooth; there might be two cavities here, and since there are 12,753 persons, there might be 25,506 carious cavities for this tooth. If four molars are present there might be four times this number, or 102,024.

I have asked Dr. Hyatt to speak briefly on the value of dental statistics and on the findings represented in these graphs (Figs. 308 to 312), which he has consented to do in the following paragraphs.

THE VALUE OF DENTAL STATISTICS IN A STUDY OF DENTAL CARIES

"We have come to recognize as an established line of research the study of specific locations of vulnerable or diseased tooth surfaces, for the purpose of developing an operative procedure for the prevention of decay. For the prosecution of this line of research we should be able to derive valuable information from a careful study of recorded findings of the frequency of caries in the several surfaces of the different teeth. This means that we need a systematic statistical service to gather data, to organize them, tabulate them systematically, and by the proper statistical technique, to draw correct conclusions from them.

"In view of the importance of dental statistics for the etiological study of dental caries, it is highly desirable that careful consideration be given to the procedure which is followed in securing these figures. The first condition for effective investigation is, of course, to see that the examinations are made thoroughly and recorded carefully and correctly. When the dental condition of a sufficiently large group of persons has been thus recorded, and correct procedure in the statistical treatment of the findings has been followed, then the information obtained and properly presented (for example in the form of graphs) will aid us in determining to what extent dental caries can be controlled or prevented.

"The procedures followed in securing the figures which are presented in the following graphs have been fully described in a paper prepared by Dr. Lotka and myself and published in the Journal of Dental Research for January, 1929.

"The data on which these graphs are based we have secured from an examination of 12,753 persons between 17 and 60 years of age. In other words these figures represent the examinations made of 2,040,480 surfaces, because proportionate allowance has been made for missing, crowned and badly decayed teeth. Caries in the different surfaces is bilaterally symmetrical. Therefore there is only shown the liability of the different surfaces of the teeth on the upper and lower right side.

"Regarding the teeth reported as missing: The number of cavities in such teeth, and their location on the teeth, are of course unknown. The same remark applies to crowned or very badly decayed teeth. We shall err on the side of conservatism if we ascribe to each surface of a missing tooth the number of cavities found, on an average, in that surface among the teeth of that particular kind that were not missing. An allowance was made in this way by means of a formula suggested by Dr. Lotka, of the Statistical Bureau of the Metropolitan Life Insurance Company. While this formula, as already stated, gives conservative correction, it enables us to secure a better picture of the relative susceptibilities of the different tooth surfaces than if no correction were made for the missing teeth.

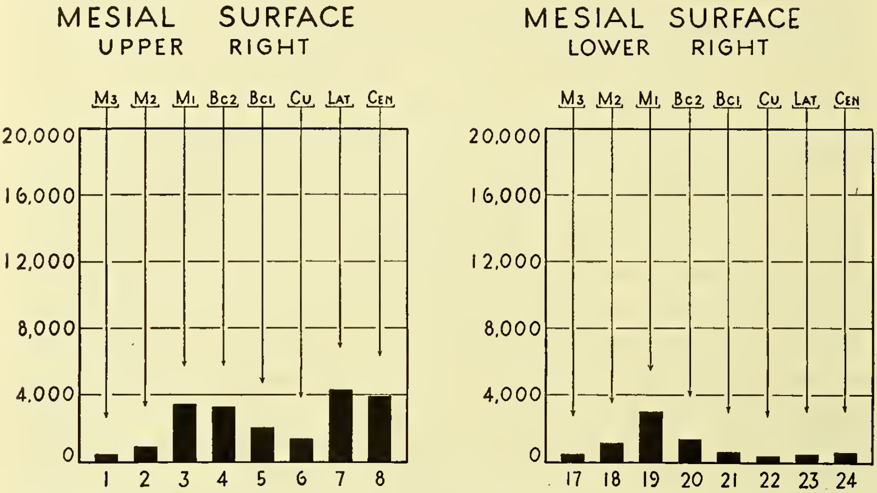


FIG. 308.—Comparative liability to decay of mesial surfaces of the upper and lower teeth of the right side.

"Fig. 308.—Shows the number of carious mesial surfaces. We cannot fail to notice that the mesial surface of the upper right lateral more frequently decays than that of any other tooth in the upper right side. The second and third molars show the least liability. In the lower

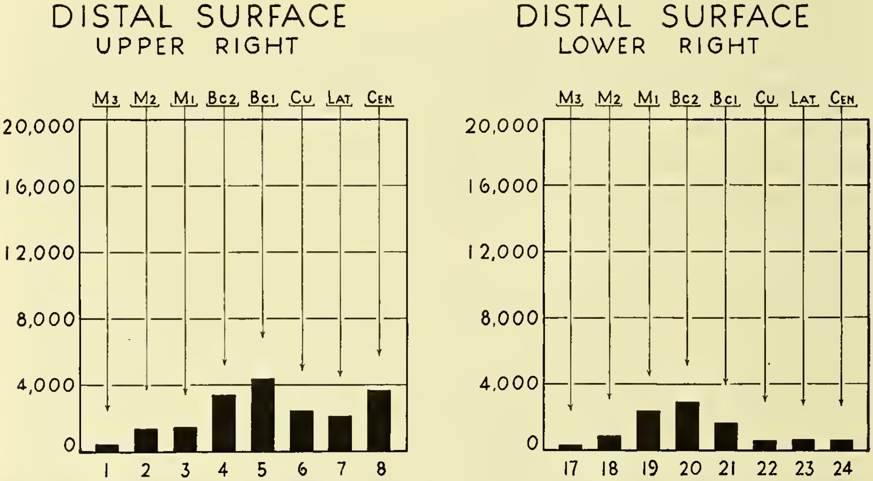


FIG. 309.—Comparative liability to decay of distal surfaces of the upper and lower teeth of the right side.

teeth the first molar shows the greatest liability, with the 2nd bicuspid, second; and the 2nd molar, third.

"Fig. 309.—Gives the liability of Distal Surfaces. Here we find that the first upper right bicuspid shows the highest liability to caries, followed by the central, 2nd bicuspid and the cuspid. The only explanation to be offered for the high frequency of decay in the distal surface of the right upper 1st bicuspid is as follows: When a compound filling or carious cavity is recorded one point has been given to each surface involved. A study of compound fillings and compound carious cavities shows that the upper right 1st bicuspid exceeds all other teeth on this side with the frequency of disto-occlusal involvement. Among the lower teeth we find that the 2nd bicuspid ranks the highest as to frequency of decay and this is due likewise to the larger number of distal-occlusal involvement.

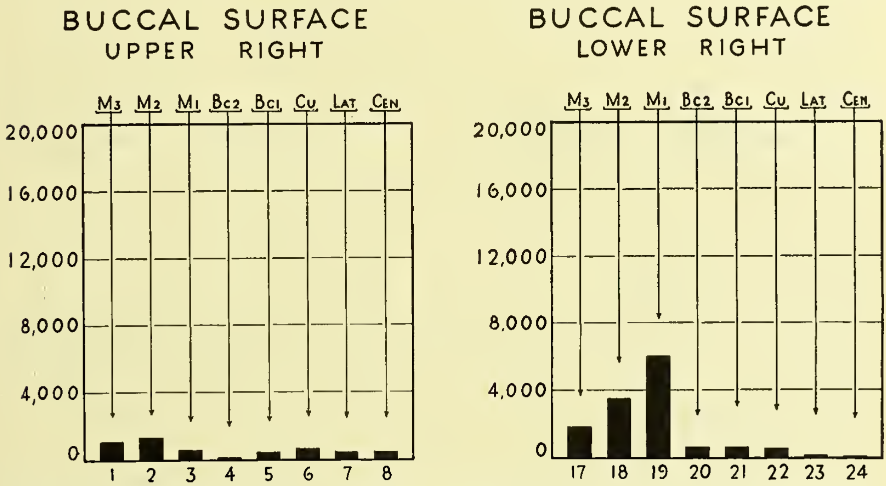


FIG. 310.—Comparative liability to decay of labial and buccal surfaces of the teeth of the right side.

"Fig. 310.—Shows the liability of Buccal or Labial surfaces to decay. The frequency of involvement of the buccal surface of the lower 1st molar is very marked, followed by the 2nd and 3rd molars. In the upper teeth it is the 2nd and 3rd molars which show the higher frequency of decay.

"Fig. 311.—In this graph some interesting contrasts are seen of lingual liability among the upper teeth. Both the bicuspids are practically free. The lateral is the highest of the three incisors, while the 1st molar has the highest frequency of all. The lower teeth show hardly any great liability to lingual caries. Inasmuch as no differentiation has been made between caries at the gingival margin and caries in the enamel, in all probability most of these carious cavities started below the enamel covering of the tooth.

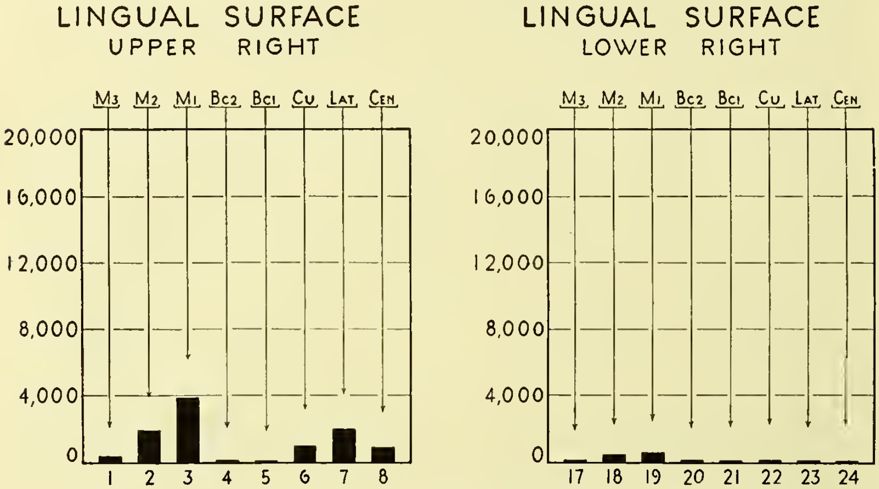


FIG. 311.—Comparative liability of decay of lingual surfaces of the teeth.

"Fig. 312.—This graph is without doubt the most interesting and instructive one from the viewpoint of learning what are the possibilities for a practical operative procedure which may greatly reduce the frequency of decay on occlusal surfaces. It is almost unnecessary to call

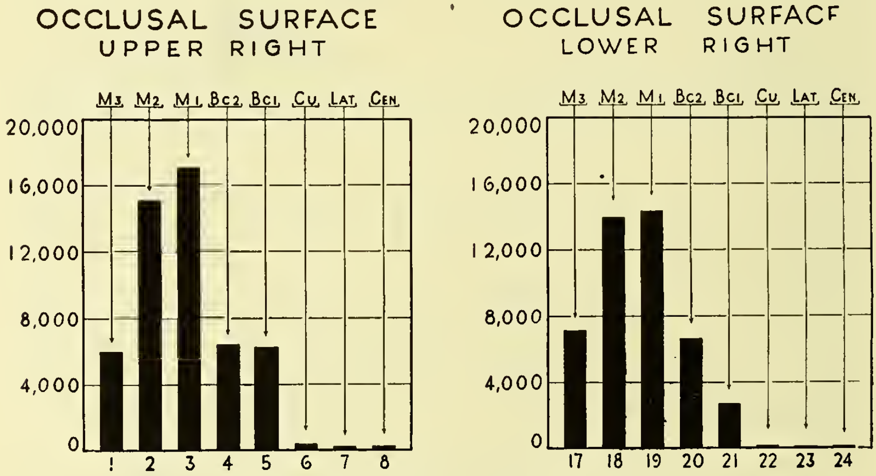


FIG. 312—Comparative liability to decay of occlusal surfaces.

attention to the fact that broad surfaces exposed to the pressure of masticating forces are more liable to caries than any of the other surfaces.

"It should be constantly born in mind that decay only starts in places which afford *undisturbed* lodgement of the fermentation of carbohydrates and bacterial life. This being true one would think that surfaces where constant friction is produced in the mastication of food should be those which are less frequently attacked by caries. In point of fact this is not the case, as is apparent from the graph.

"A histological study of tooth *formation* as well as of tooth structure is necessary to explain the reason for the higher frequency of decay on any surface and the particular spot in each surface where decay generally starts."

In an interesting brochure published by the University of Minnesota Press, 1928, Doctor Peter J. Brekhus offers some important statistics, based on an examination of 9,450 patients from the clinics of the College of Dentistry of the University of Minnesota. These statistics are evidently reliable findings with reference to the following questions, viz.:

1. At what ratio are teeth lost?
2. At what ages do the losses occur?
3. Are there any sex differences in the loss of teeth?

Unfortunately the cause of removal of these teeth is not stated. However, the findings as evidenced by the accompanying table of Doctor Brekhus may be considered reliable and as stated by the author a true index of the dental conditions of the general public. See Fig. 313. An analysis of these findings reveals the following significant facts, viz.:

1. The lower first molar is the first to disappear. At the age of ten, 10% of boys and 15% of girls had lost this tooth. The increase in the rate of loss is very rapid, there being at the age of fifteen, 50% loss in boys and 35% in girls. At the age of twenty, there is a loss of 40% and 47% in boys and girls respectively, while at forty years, the prime of life, 63% of men and 75% of women had lost this tooth.

2. The teeth are lost in the following orderly sequence, viz.: lower 6, upper 6, upper 5, upper 4, lower 7, upper 7, lower 5. Of the upper anterior teeth, upper 2 disappears first, then upper 1, then upper 3; then follow lower 4, lower 1, lower 2 and lastly lower 3 in the order mentioned. This sequence indicates that the posterior teeth are first to be lost and the lower anteriors remain the longest.

3. The general average of loss is about ½ of 1% greater on the left than on the right side.

4. Up to fifteen years of age the comparative loss of teeth in males and females is slight (with the exception of lower 6) but after that age the loss is greater in women than men up to age 60 (10 to 15%) when the margin again narrows. Fig. 314.

TABLE I

Relative Loss of Teeth During the Ages from 10 to 75 Years in Males and Females

(Percentages based on 9,450 patients)

Age		10	15	20	25	30	35	40	45	50	55	60	65	70	75
Lower Six	M.	10	30	40	45	50	55	63	70	72	77	80	85	88	90
	F.	15	35	47	57	65	72	75	78	82	83	86	88	92	92
Upper Six	M.	5	15	23	35	40	50	55	62	69	75	81	86	89	93
	F.	5	15	24	35	47	56	67	72	78	80	85	88	92	93
Upper Five	M.	0	3	11	18	29	40	48	57	62	68	75	80	86	90
	F.	0	3	14	30	41	55	65	72	78	82	85	90	92	93
Upper Four	M.	0	4	11	18	29	37	46	55	62	67	75	80	86	90
	F.	0	3	14	27	40	55	63	73	77	82	84	88	91	94
Lower Seven	M.	0	2	8	16	25	35	45	55	63	67	76	82	87	90
	F.	0	3	17	25	39	50	62	70	76	80	85	88	92	95
Upper Seven	M.	0	0	3	12	21	33	44	60	64	73	79	83	90	93
	F.	0	1	10	20	32	45	58	68	73	78	82	88	92	93
Lower Five	M.	0	3	9	13	19	26	33	41	49	56	64	70	75	79
	F.	0	3	12	22	30	42	50	60	65	72	76	80	86	90
Upper Two	M.	0	2	6	10	20	30	39	48	55	62	69	74	81	85
	F.	0	2	13	18	33	41	53	63	69	75	80	86	89	96
Upper One	M.	0	¼	2	10	18	25	35	44	51	60	68	75	82	88
	F.	0	2	10	18	29	40	50	60	67	75	79	83	89	94
Upper Three	M.	0	0	½	6	14	22	32	45	49	58	66	75	82	88
	F.	0	0	6	15	26	40	50	60	67	72	78	81	87	95
Lower Four	M.	0	0	1	6	10	15	23	30	40	47	58	64	70	73
	F.	0	2	4	9	17	26	36	45	54	64	70	75	82	86
Lower One	M.	0	0	1	2	6	12	20	28	39	48	58	65	72	76
	F.	0	0	3	6	10	17	26	33	43	50	60	68	78	86
Lower Two	M.	0	0	¼	1	6	10	18	25	34	45	57	62	70	74
	F.	0	0	2	4	10	16	26	36	43	54	60	66	78	86
Lower Three	M.	0	0	¼	1	4	7	15	23	33	42	53	60	66	69
	F.	0	0	1	4	9	16	25	36	41	53	60	65	78	85

Fig. 313.—Statistics showing relative loss of teeth. (Courtesy of Dr. Peter J. Brekhus and the University of Minnesota Press.)

Caries of Enamel.—Penetration of the enamel by the acids of fermentation takes place via the intercementing substance between the enamel rods. This substance is much less dense than the rods and consequently less resistant to the action of acid. According to Harold F. Hawkins,[1] its density varies in different teeth. The same investigator states that in mouths showing great susceptibility to decay the intercementing substance is less dense than in immune mouths. He has found that the pH values of starches and sugars range from 4.5 to 3.2 and that the intercementing substance is readily dissolved by lactic acid at pH 4 or greater concentrations.

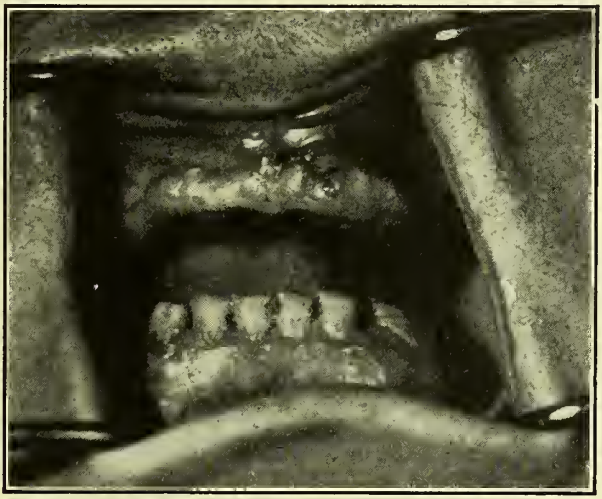


FIG. 314.—Apparently edentulous maxilla. Radiograms revealed an impacted cuspid and two impacted upper third molars.

The principal points of localization are in protected spots, such as pits and fissures, proximal surfaces and the gingival third of labial and buccal surfaces. Black makes the statement that 98% of cavities are found in these areas. Food deposits here, the bacterial plaque agglutinates itself to the underlying surface, acid formation begins and a whitened area of decalcified enamel occurs on the surface. The acid then penetrates into the enamel via the cement substance between the rods, and is gradually followed by the germs which create additional amounts of acid, the process continuing in this manner until the enamel covering is penetrated at the dento-enamel junction. Fig. 315. Owing to the resistance of the rods to the decalcifying process they will often hang together for a long time before breaking down. Finally, however, the cement substance between the globules is dissolved, rods and globules finally succumbing. On smooth surfaces, the area of decalcification presents a cone shape with its base on the surface and its point gradually penetrating to the amelo-dentinal junction. In pits and fissures, owing to the convergence of the rods surrounding them, the picture is reversed, the base of the cone being at the dentino-enamel junction and the point at the surface. See Fig. 306. Caries is most frequently found in these latter areas since food impactions most readily occur here and the micro-organisms are most easily retained. As a result, the highest degree of acidification is present in cavities of this type and the acid will more readily eat its way across the rods in the deepest parts.

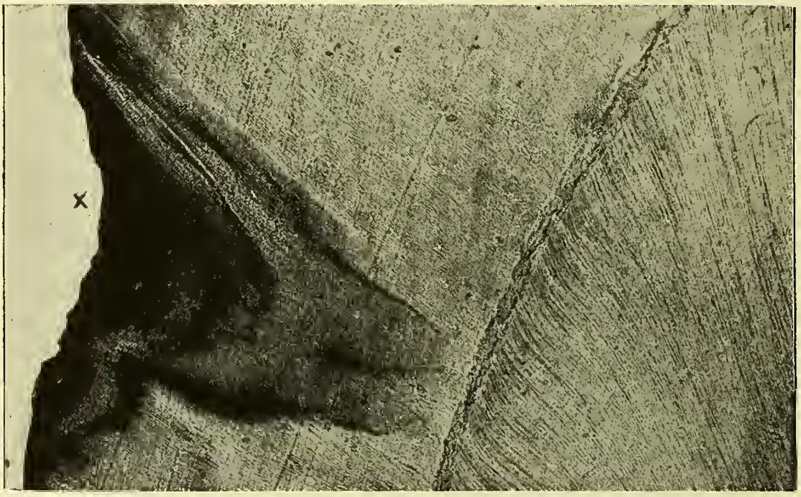


FIG. 315.—Caries of enamel. Caries has penetrated nearly to the dento-enamel junction following the lines of the enamel rods. (From Dr. G. V. Black's Operative Dentistry.)

As soon as decalcification has penetrated to the dentino-enamel junction, the acid of decay spreads out along the surface of the dentin and begins to eat its way backward via the inter-rod substance, causing "backward decay" of enamel. As a result, the enamel is finally completely broken down, the rods and globules falling apart and becoming disintegrated and washed away by the saliva. As soon as the dentin is reached, caries of this tissue begins and often progresses deeply before the enamel rods fall away to any great degree. This is particularly the case in pit and fissure cavities, but is also seen in smooth surface decays.

The claims of C. F. Bödecker[3] that the enamel contains a higher percentage of organic matter than was formerly supposed have been previously mentioned in the chapters on "Prevention." He claims that the enamel is composed of globules built up into rods surrounded by sheaths of organic matter, each rod sheath being separated by an inter-cementing substance of inorganic material. He states that the

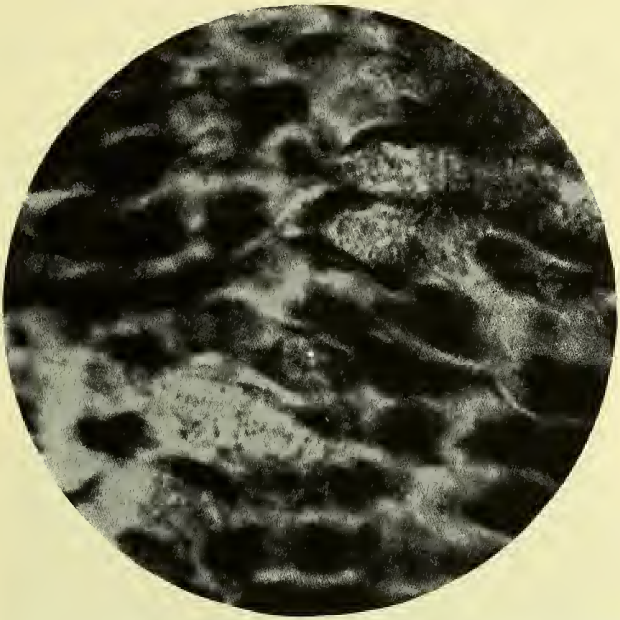


FIG. 316.—Micro-organisms penetrating enamel. Enamel rods surrounded by "rod sheaths" of Bödecker are seen highly magnified. (Courtesy of Dr. Charles F. Bödecker and "The Dental Cosmos.")

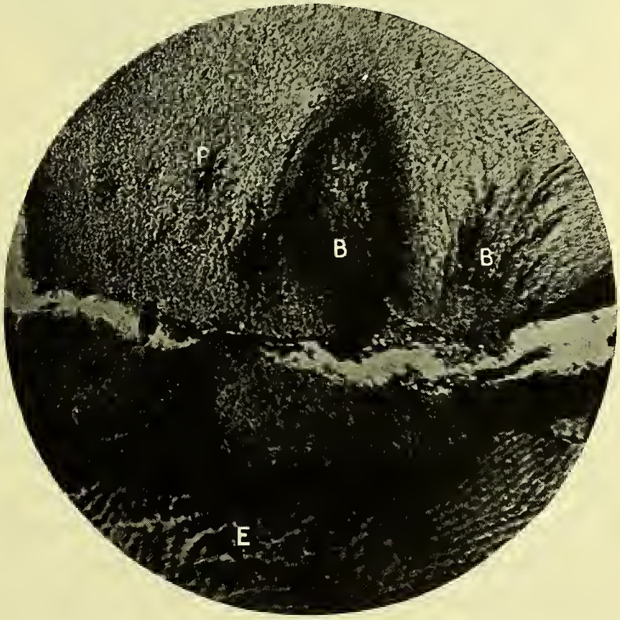


FIG. 317.—Plaque of food debris, P, with bacterial growths penetrating it at B, B from the surface of the underlying enamel, E. Approximate enlargement 250 diameters. (Courtesy of Dr. Charles F. Bödecker and "The Dental Cosmos.")

rod sheaths and the inter-cementing substance are more resistant to acids, penetration of these acids and the germs occurring along the rods between the sheaths. His photo-micrographs and drawings appear to indicate that caries of enamel is in many respects similar to caries of dentin. These claims of Dr. Bödecker have not been substantiated by other investigators and are not as yet freely accepted by the profession. Figs. 316 and 317.

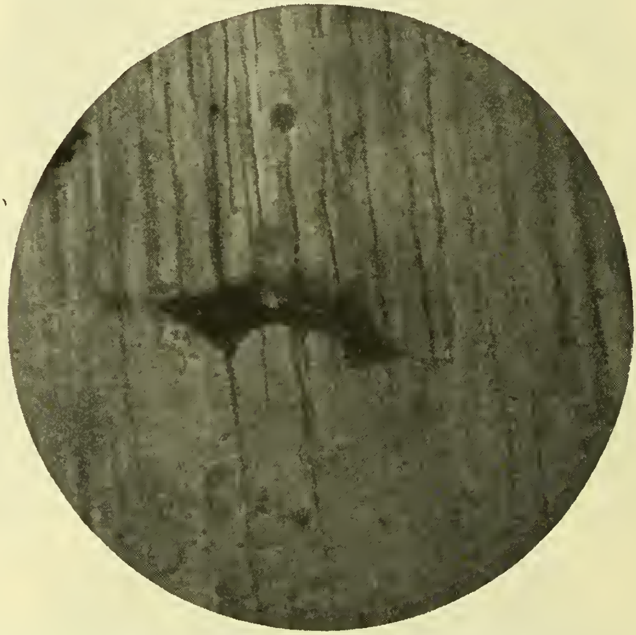


Fig. 318.—Dentin of crown. Interglobular spaces filled with air, with tubules passing through. High power. (Courtesy of Dr. John B. Stein.)

Professor Seiji Kato,[4] a Japanese investigator of the Nippon Dental College, has presented somewhat similar findings to those of Professor Bödecker with reference to the histologic structure of enamel. I have previously deplored the many differences in the findings of histologists and histo-pathologists with reference to the dental and oral tissues, their structure, nutrition and pathology. It is high time that these findings should be stabilized and correlated for the good of the profession.

Caries of Dentin.—When the acid produced by the bacteria has penetrated to the dentin, decalcification of this structure begins. Shortly after the enamel rods begin to break down and fall out, the acids, followed by the bacteria, spread out along the surface of the dentin and find entrance into the fine peripheral tubules with their anastomatic loops and into the interglobular spaces. The dentin is decalcified in advance of the germs, which readily advance deeper and deeper into the tubules. Fig. 318.

The lumen of the tubule is enlarged from pressure of the bacteria, and the tubule wall becomes thinner from the action of the acid and the bacterial ferments. In many cases, the tubule is enlarged along its entire course, giving it the so-called "pipe-stem" appearance. In other instances, oval enlargements occur here and there, the tubules presenting a varicose appearance. The tubule wall is finally penetrated and a "liquefaction focus" is formed, the acid and the germs escaping into the dentin matrix and destroying it. The organic matrix frequently remains for a while after the calcium salts are dissolved, being later destroyed by the putrefactive bacteria. Figs. 319 to 322.

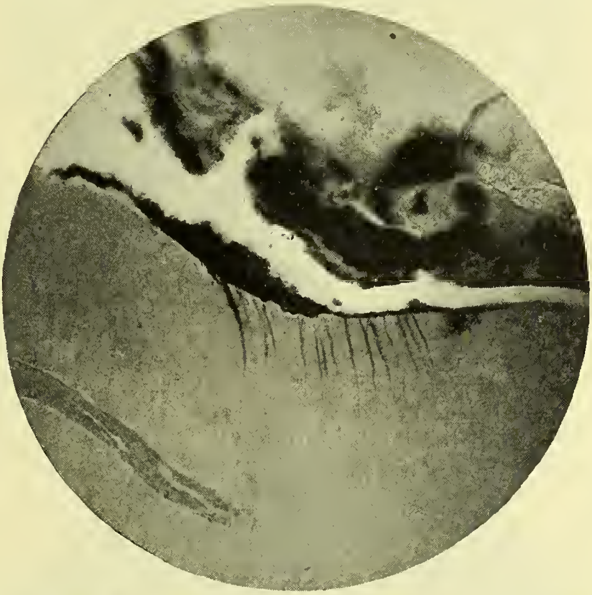


FIG. 319.—Bacterial plaque and early stage of tubule infection. (Courtesy of Dr. Harold K. Box.)

Penetration of the acids, followed by the germs, produces a conical shaped area, with its base at the amelo-dentinal junction, its apex toward the pulp. The upper layers may be completely or partially dissolved, the next are soft and readily scooped out, while the deepest layers are harder. With a small cavity orifice, occasionally a large area of dentin may be softened by decalcification and yet the organic matrix is not broken up. Marked cases of this nature, however, are rare.

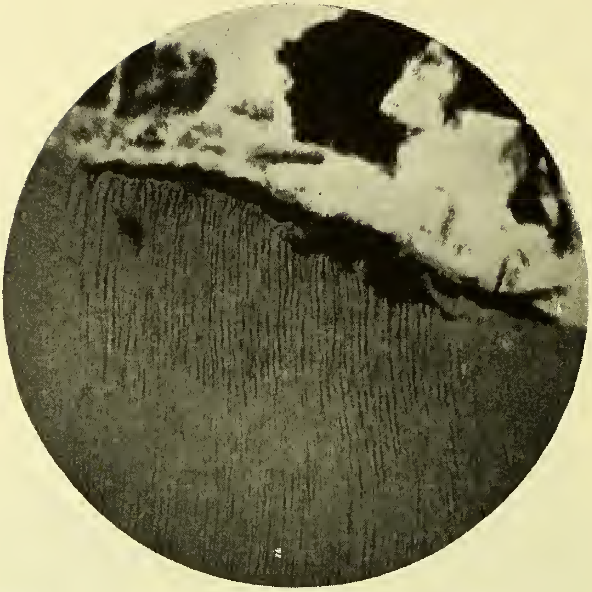


FIG. 320.—Bacterial plaque and more extensive tubule infection. (Courtesy of Dr. Harold K. Box.)

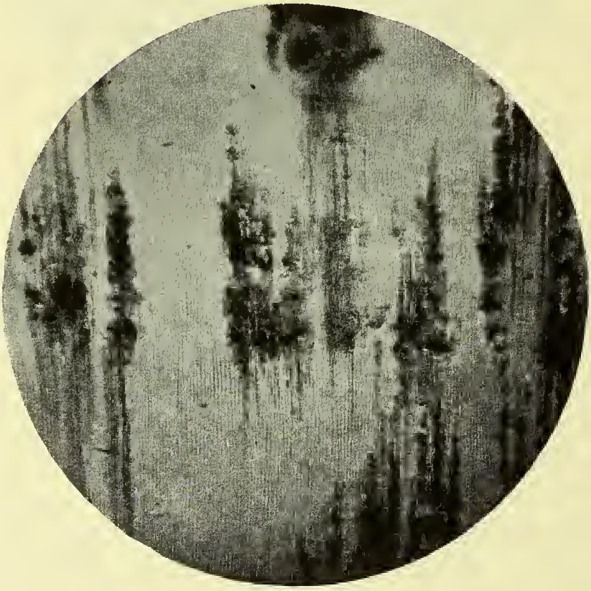


FIG. 321.—"Pipe stem" tubules and small liquefaction foci. (Courtesy of Dr. Harold K. Box.)

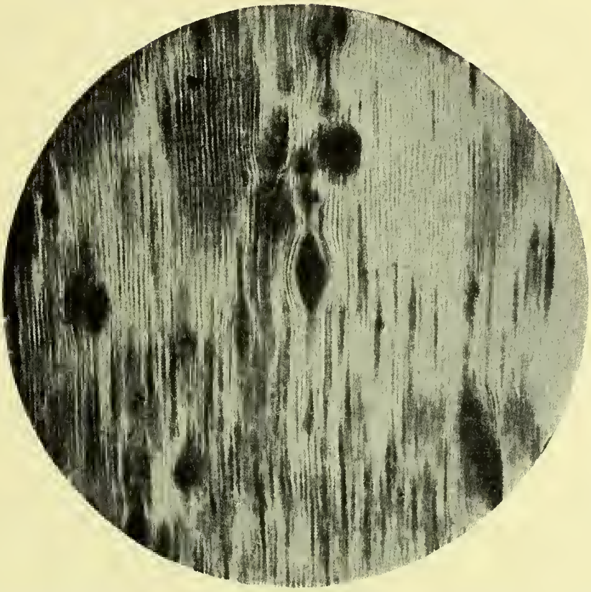


FIG. 322.—Larger liquefaction foci in caries of dentin. (Courtesy of Dr. Harold K. Box).

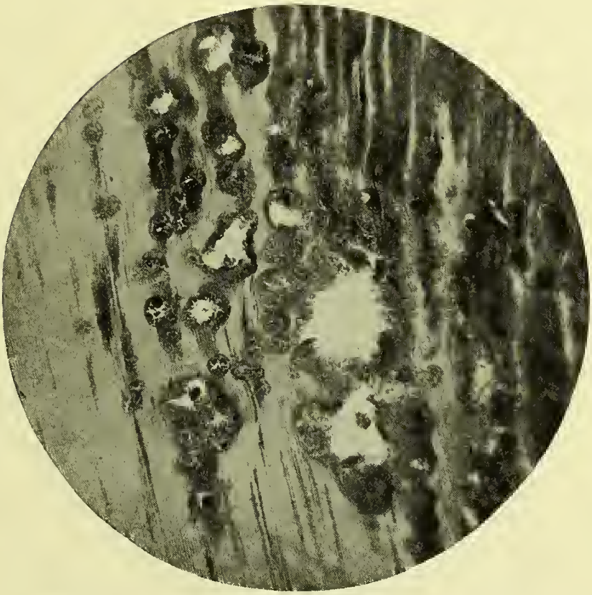


FIG. 323.—Fusion of liquefaction foci. (Courtesy of Dr. Harold K. Box.)

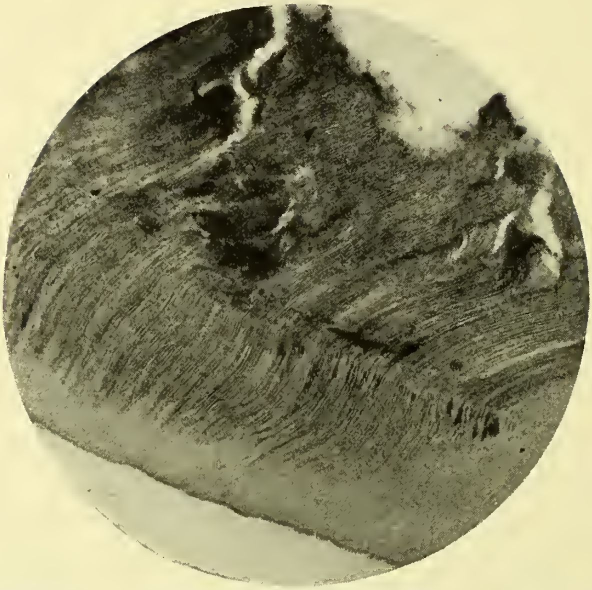


FIG. 324.—Later stages in caries of dentin. Cavity formation. (Courtesy of Dr Harold K. Box.)

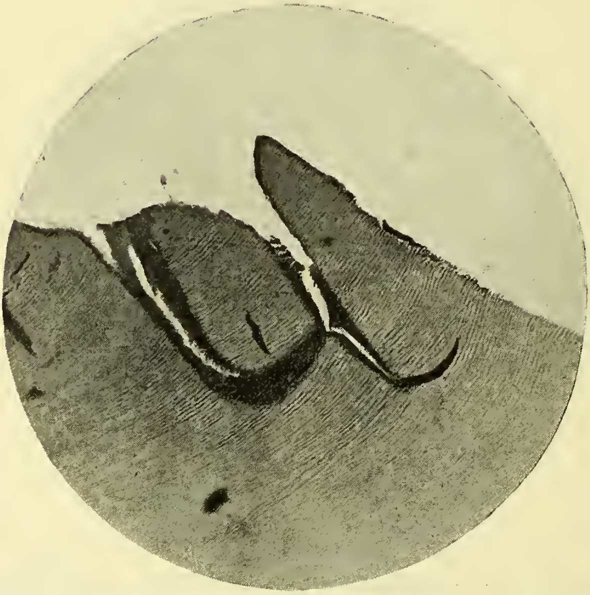


FIG. 325.—Masses of dentin undermined by bacterial invasion. (Courtesy of Dr. Harold K. Box.)

After the tubule walls are penetrated, liquefaction foci are formed, which enlarge, coalesce, and destruction of the dentin matrix is accomplished through the action of the acids and germs. If uninterrupted, the process proceeds until exposure of the pulp occurs. Pulp infection frequently occurs far in advance of exposure of the organ. Caries in extreme cases may enter the pulp-chamber and canal and progress backward, producing "backward decay" or "secondary caries" of dentin. It may also perforate the side of a root or the floor of the pulp chamber in molars. Figs. 323, 324 and 325.

In vital teeth, immediately beneath the deepest layers of partially decalcified dentin is occasionally seen a translucent layer known as the "translucent zone" or "transparent zone" of Tomes. Black interprets the phenomenon as due to death of the dentinal fibrils and claims that it causes hypermia of the underlying pulp. However, the majority of authorities claim that it is a vital phenomenon, attributing it to tubular calcification as the result of stimulation to increased activity of the odontoblastic layer of the pulp.

Caries of Cementum.—Caries of cementum occurs most frequently in cases of receded gingivae on the gingival third of labial and buccal surfaces. Its features are essentially the same as caries of dentin, being modified by the histologic structure of this tissue. Penetration of the acids and bacteria occurs via Sharpey's fibres, the lacunae and canaliculi. Its progress is usually more rapid than caries of dentin.

CLINICAL FEATURES OF CARIES IN VARIOUS LOCALITIES

Although the progress of caries is fundamentally the same in all localities, there are certain important variations from the characteristic features of this pathologic condition which have a definite bearing on cavity preparations on various surfaces of the teeth. These features will now be stressed.

1. Decays in Pits and Fissures.—The characteristic features of this type of cavity are usually:—

1. A small opening, or orifice.
2. Spreading in cone shape in the enamel, the base of the cone being in the deepest part.
3. Rapid burrowing along the dento-enamel junction.
4. Spreading in the dentin in conical form, the base being at the surface of the dentin, the apex pointing toward the pulp.
5. Great decalcification of the dentin in advance of decomposition of the organic matrix.

These cavities are the simplest forms to treat. However, early detection and filling is imperative, owing to their tendency to deep burrowing and lateral spreading in the dentin under a small enamel orifice. Occasionally on occlusal surfaces, this spreading is unsuspected until the cavity is opened, when it will be sometimes found to have undermined the mesial or distal marginal ridge or to have endangered the recessional lines of the pulp. This is especially the case in occlusal cavities in bicuspids, owing to the small size of these teeth.

2. **Proximal Surface Decays on Bicuspids and Molars.**—The chief clinical features of these cavities are:

1. The inception of decay is obscured from view and often difficult to detect.
2. Tendency to wide spreading bucco-lingually.
3. Liability to early undermining of the occlusal marginal ridges from extension of the decay along the amelodentinal junction.
4. Extensive spreading gingivally and toward the axial line angles.
5. Likelihood of a recurrence of decay after filling at the bucco- and linguo-gingival angles of the cavity margin.
6. Tendency to a similar recurrence at the gingival margin after filling, especially if the contact points allow impaction of food into the interproximal spaces.

The long mesio-buccal horn of the pulp, especially in upper and lower first molars is a menace in this type of cavity. The extension of the recessional lines of the pulp from the pulp cornuae toward the cusps, should constantly be borne in mind in the preparation of proximal surface cavities and also in extensive occlusal surface decays which have burrowed deeply and widely bucco-lingually. The danger of pulp exposure is always very great in the region of the recessional lines of the pulp. In proximal surface decays in bicuspids and molars, the cavity may sometimes be concealed until the marginal ridge breaks through. In some instances the pulp may be exposed before breaking down of the marginal ridge, from deep burrowing of the decay. Especially in bicuspids, the small size of the tooth and thinness of the dentin overlying the pulp demands early treatment. The introduction of the bite-wing film into dentistry now makes early diagnosis of proximal surface cavities a comparatively simple procedure.

Secondary extensions gingivally of proximal surface decays are frequently due to flat or open contacts which allow impaction of food masses, roughening of the surface and decalcification from the resultant action of the acids of fermentation. Following this, recession of the interdentinal papilla and pocket formation is likely to result. If there is complaint of pain in the interproximal space from food lodgements, the teeth should be separated and proper contacts built to prevent impaction of food. If this is not done acid fermentation and cavity formation or putrefaction, together with gingival and pericemental disturbances are likely to supervene. In the preparation of the cavity margins, they should usually be extended well under the free margin of the gums to prevent a recurrence of the decay. The gingivae should also receive proper stimulation in an effort to restore them to a normal condition.

On proximal surfaces, caries usually begins slightly gingivally to the contact points. With perfect marble contact points and healthy interproximal gingival tissues which normally fill the interproximal space, this is not likely to occur. However, if the contacts are not perfect and the interproximal papillae are slightly receded, germs and food masses locate and a whitened area of decay is soon likely to make its appearance. This forces the gingival tissues further away and the carious area further spreads buccally and lingually and also gingivally. Usually the bucco-lingual spreading is not further than the buccal and lingual axial line angles, these areas being relatively immune. This relative immunity of the angles is due to the free excursions of food masses, these masses being forced over them as a result of the occlusal relationships of the cusps of the teeth of the opposing jaw. However, if caries extends across these angles it is, in poorly cared for mouths likely to unite with carious areas on the gingival third of buccal or labial surfaces and nearly or in some instances completely encircle the tooth.

Usually the carious area is wider bucco-lingually than occluso-gingivally. Black[5] states that in 10,000 persons examined, decay spreads beyond the angles in only 1 case per 1,000. Spreading beyond the angle occurs only in cases where artificial cleansing is neglected, the tooth is rotated, mastication is defective or inadequate or the occlusal relationships are imperfect. Buccal and lingual margins of proximal surface cavities on bicuspids and molars should be carried out to the neighborhood of the angles for reasons which should now be clear to the student. Fig. 326.

3. Proximal Surface Decays on Anterior Teeth.—The clinical features here are:

1. The triangular or V shaped proximal surface of the incisors and cuspids;

2. Tendency for the decay to extend labially and lingually and undermine the labial and lingual enamel plates;

3. Danger of its extending incisally with resultant weakening or destruction of the angles;

4. Similar probability of its extension gingivally, as mentioned with bicuspids and molars; and

5. The likelihood of endangering the horns or recessional lines of the pulp, which latter extend toward the angles.

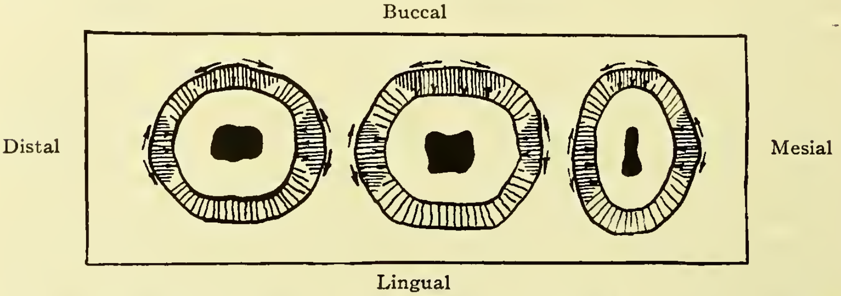


FIG. 326.—Diagram representing cross sections of the crowns of a bicuspid and two molars. The darkened areas in the buccal and proximal surfaces represent the areas of susceptibility to decay. The arrows show the direction of spreading of caries on these surfaces toward the angles, represented by whiter areas. The angles are relatively immune.

Owing to the small size of these teeth, the danger likely to supervene from caries, and the importance of avoidance of display of filling materials, early diagnosis and treatment is doubly important. The necessity for extension of cavity margins gingivally, labially and lingually is of equal importance as in similar cavities in posterior teeth and for the same reasons.

4. **Gingival Third Decays.**—The essential clinical features are characteristic:—

1. The carious area usually begins as a white line in the center of the gingival third of labial and buccal surfaces.

2. Marked sensitivity is usually characteristic.

3. The decay generally spreads mesially and distally near or quite to the axial line angles.

4. Bell crowned teeth or teeth with markedly convex surfaces exhibit a great susceptibility to this type of cavity on account of the fact that the bolus of food during mastication will be deflected from the tooth at the gingival third, which will thus be deprived of the scouring effect of the bolus.

5. If the angles are passed, union of the cavity with another area of decay on the proximal surface is likely to occur, as on posterior teeth.

6. This is the least frequent of the usual types of decay.

7. Often, many teeth are affected.

8. It is more frequently found in the later periods of life; though it is occasionally seen in childhood and adolescence where proper cleansing methods are badly neglected. Fig. 327.

These cavities are seen in all ages and conditions. Remnants of Nasmyth's membrane, faulty hygiene and defective tooth structure may be responsible for their inception in the young. Mucinous salivas facilitate the agglutination of food masses and the formation of the bacterial plaque here. In the aged, the gingivae are often receded, exposing the cemento-enamel junction and the cementum of the root to the action of the exciting causes and producing so-called "senile decay." There is always a tendency to recurrence, unless cavity margins are extended under the marginal gingiva where they will be protected, mesially and distally to the angles, and incisally or occlusally to self-cleansing areas. Fig. 328.

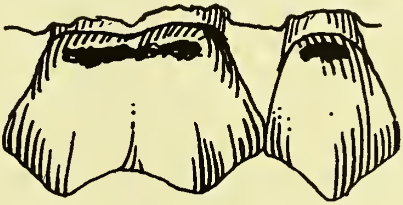


Fig. 327.—Gingival third decays

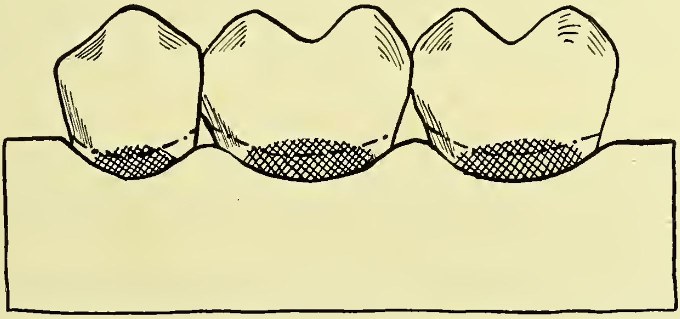


Fig. 328.—Areas of caries susceptibility in the gingival third of buccal surfaces.

REASONS FOR EXTENSION OF GINGIVAL MARGINS

Clinically, it is well known that gingival margins of all cavities, when extended under the free gingival margin are protected and less susceptible to decay. The reasons for this have not been definitely determined. Occasionally, gingival third cavities occur in exceptionally well cared for mouths where no trace of the bacterial film or food deposits, or other apparent causes are discovered. Doctor John Oppie McCall in an article appearing in the Journal of Dental Research, December, 1924–1926, pp. 461–472, entitled "Studies in the Etiology of Approximal Dental Caries," presents a convincing theory as to why gingival margins are often protected when extended under the gingiva and why caries is likely to occur or recur in gingival areas on proximal, labial and buccal surfaces in the apparent absence of the ordinary well-understood exciting causes. According to this theory, the secretion from the gingival crevice is normally alkaline in reaction when originating from the normally alkaline blood streams of healthy gingival tissues. This would apparently tend to neutralize the acids of decay along the gingival margin of cavities extended into this area and thus account for their relative immunity to a recurrence of the carious process here. The gingivae are subject to inflammatory disturbances from local mechanical causes, systemic conditions and traumatic occlusion. As a result the alkalinity of the blood in the affected area is changed to an acid reaction, which produces a like change in the secretion in the gingival crevice. This acid gingival-crevice secretion may either cause a roughening or partial disintegration of the enamel and cementum, or offer a more inviting field for the location and growth of aciduric micro-organisms, either of which condition would stimulate the carious process and cavity formation. Although Doctor McCall has offered no definite proof of this theory, it is certainly worthy of consideration and further investigation.

Bibliography

1. Burchard, H. H. and Inglis, O. E.: "Dental Pathology and Therapeutics," 5th ed., Lea and Febiger, Philadelphia, 1915, p. 357.
2. Hawkins, Harold F.: Dental decay, Jour. Amer. Dent. Assoc., May 1929, p 781.
3. Bödecker, Chas. F.: Report of further investigation on organic matrix in enamel, Jour. Dental Research, vol. VI, no. 2, p. 117.
4. Kato, Seiji: The histological study on human enamel, Shikwa Shimpo, vol. XXI, nos. 5, 6, 7, 8, 1928.
5. Black, G. V.: "Operative Dentistry," vol. I, p. 88.

Bödecker, Chas. F.: Bacterial invasion of enamel in dental caries, Dental Cosmos, vol. LXIX, Oct. 1927, p. 987.

Chase, Sam'l W.: Origin, structure and duration of Nasmyth's membrane, Anatom. Record, vol. 33, no. 5, Sept. 1926, p. 357.

Mummery, J. Howard: "Microscopic and General Anatomy of the Teeth."

Causch, Douglas E.: Dental Cosmos, Feb. 1905, p. 165.

Bunting, R. W. and Wixon, Florence: Report of work on dental caries, Jour. Nat. Dent. Assoc., Jan. 1917.

McGehee, W. H. O.: Prevention dental caries, American Dentist, Sept. 1915.

McGehee, W. H. O.: Relation of saliva to dental caries, New Jersey Dental Jour., vol. V, no. 7, July 1916, p. 257.

McGehee, W. H. O.: Prevention of dental caries, Dental Summary, vol. XXXVIII, no. 8, Aug. 1918, p. 597.

McGehee, W. H. O.: Prevention of dental caries, Dental Summary, vol. XXXVI, no. 12, p. 1019.

McGehee, W. H. O.: Causes and prevention dental caries, Dental Summary, vol. XXXVII, no. 9, p. 635.

Broderick, F. W.: Dental caries and pyorrhea, Dental Magazine and Oral Topics, July 1929 to April 1930.

CHAPTER XI

PREPARATION OF CAVITIES (*Continued*)

NOMENCLATURE—TECHNICAL PROCEDURES

There is no phase of dentistry which is of greater importance to the general practitioner than that of cavity preparation. Inasmuch as the daily work of the average dentist is concerned largely in the adaptation into prepared cavities of filling materials for the restoration of lost tooth structure, it might almost be considered the keynote to successful dental practice of today. If the cavity be improperly prepared, if the foundation be formed along incorrect lines, the superstructure—the filling material—will be placed on insecure ground and will succumb easily to the stresses later to be brought to bear upon it.

The technic of the preparation of cavities was placed on a more definite scientific basis than it formerly occupied by the lamented Doctor G. V. Black a number of years ago. His theories incident to "extension for prevention," the bevelling of enamel margins and the adoption of the "box" form in the preparation of the internal parts of cavities have been the accepted practice among modern operators. "Black" cavity preparation with certain modifications is officially recognized, advocated and taught in all of the dental colleges of this country.

Previous to the work of Black, there was no definite system of instrumentation, each teacher and operator largely using his own ideas as to how cavities were to be prepared, fillings made and other procedures performed. The introduction of his system brought order out of chaos and was to a great degree responsible for the remarkable advances in operative procedure made during the past thirty years.

Teachers and practitioners found on consulting his works that the cavity-forms therein advocated do not admit of the formation of a groove on the gingival wall of proximal cavities, as previously taught. They learned that a groove here would interfere with the source of nourishment via the dentinal tubules, to that portion of the tooth separated from its pulpal connections by the groove and would also mechanically weaken that area. They likewise perceived that in none of his writings was there advocated the now obsolete practice of weakening labial, buccal or lingual walls by the placing of grooves in those areas for the retention of fillings. They also found, after careful investigation, that the proper extension of the marginal outline into immune areas is not the extremely radical procedure they may have imagined it to be.

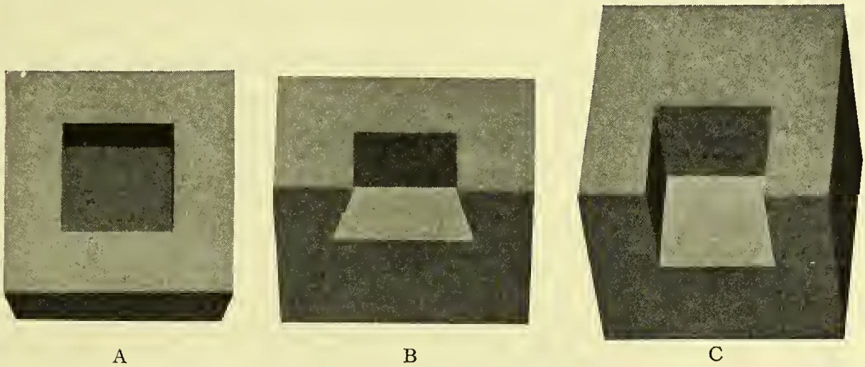


FIG. 329.—Mortise forms. A, the simple mortise on one surface. B, the simple dovetail mortise. The plaster block has been sawed in half to show the inside of the box form which has been dovetailed on two opposite walls. C, the simple mortise form involving two surfaces.

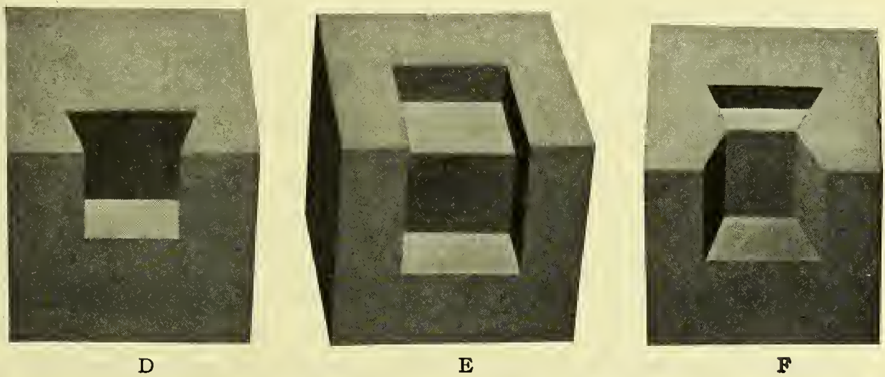


FIG. 330.—Mortise forms. D, method of dovetailing the simple mortise form involving two surfaces, thus making it retentive in form. E, auxiliary mortise or step form. F, auxiliary or compound dovetail mortise (dovetailed step form).

Before taking up a discussion of the technical procedures incident to the preparation of cavities, it is necessary for the student to acquire a nomenclature. By nomenclature is meant a system of sounds, words, or signs, by which individuals of the same race, profession or calling are enabled to understand each other. The profession of dentistry has a nomenclature of its own, which consists of numerous technical names, terms or phrases used in that science. A knowledge of the nomenclature or terminology of cavity preparation is essential.

For the reader to understand many of the terms to be mentioned in a study of the nomenclature of the subject, it is necessary for him to realize in the beginning that all cavities are given a box or mortise shape, or some modification of this form, the inner walls of the box being plane surfaces joining each other to form definite line and point angles as will be seen on examination of the mortise forms shown in Figs. 329 and 330.

NOMENCLATURE OF CAVITY PREPARATION

Angle.—The union of two surfaces along a definite line (*Line Angle*), or of three surfaces at a point (*Point Angle*).

Cavo-Surface Angle.—The angle formed by the junction of the walls of the cavity with the surface of the tooth.

Axial Line Angle.—A line angle running parallel with the long axis of the tooth.

Pulpal Line Angle.—One running horizontally to the long axis of the tooth.

Wall.—One of the internal boundaries of a cavity.

Margin.—The junction of the walls of a cavity with the surface of a tooth.

Marginal Outline.—The shape of the cavity along its margins.

Dento-enamel Junction.—The line representing the junction of the enamel and dentin.

Enamel Wall.—That part of the wall of a cavity composed of enamel.

Dentin Wall.—That part of the cavity wall consisting of dentin.

Seat.—In simple cavities the bottom or floor of the cavity, either the axial or pulpal wall; in proximo-incisal and proximo-occlusal cavities, the gingival wall.

Step.—The auxiliary portion of the compound mortise form, consisting of the axial and pulpal walls in complex cavities.

Cavity Names.—Cavities in the teeth take the names of the surfaces in which they occur.

Cavities may be **grouped** from the standpoint of their situation into

A. *Simple Cavities.*—Labial, buccal, lingual, mesial, distal, occlusal.

B. *Complex Cavities.*—Mesio-incisal, disto-incisal, mesio-occlusal, disto-occlusal, linguo-occlusal, bucco-occlusal, mesio-disto-occlusal, mesio-disto-incisal.

Proximal Cavity.—A mesial or distal cavity.

"M.O.D." Cavity.—A phrase used by some to express a Mesio-disto-occlusal cavity.

"M.I.D." Cavity.—Mesio-disto-incisal cavity.

Cavities may be **classified** from a standpoint of similarity of treatment into

I. Pit and Fissure Cavities.
- A. Cavities in the occlusal surfaces of bicuspids and molars; Class I cavities.
- B. Cavities in the occlusal two-thirds of buccal and lingual surfaces of molars; Class I cavities.
- C. Cavities in the lingual surfaces of upper incisors; Class I cavities.

II. Smooth Surface Cavities.
- D Cavities in the proximal surfaces of bicuspids and molars; Class II cavities.
- E. Cavities in the proximal surfaces of incisors and cuspids not involving the incisal angle; Class III cavities.
- F. Cavities in the proximal surfaces of incisors and cuspids which involve the incisal angle; Class IV cavities.
- G. Cavities in the gingival third of labial, buccal and lingual surfaces; Class V cavities.

Cavity Walls Named.—Cavity walls take the names of the surfaces on which they are placed, such as labial, buccal, incisal, occlusal, lingual, mesial, distal.

Walls in Buccal and Lingual Cavities.—Mesial, distal, occlusal, gingival, axial.

Walls in Proximal Cavities in Anterior Teeth.—Labial, lingual, gingival, axial.

Walls in Proximo-incisal Cavities.—In the proximal portion: labial, lingual, gingival, axial. In the step portion: labial, lingual, mesial (or distal), pulpal.

Walls in Proximo-Occlusal Cavities.—In the proximal portion: gingival, buccal, lingual, axial. In the occlusal portion: mesial (or distal), buccal, lingual, pulpal.

Distinction between the axial and pulpal walls.—The axial wall is that wall lying nearest the pulp in cavities occurring on axial surfaces, while the pulpal wall overlies the pulp in occlusal cavities, being the floor of these cavities, and runs horizontally to the axial surfaces. Complex cavities have both an axial and a pulpal wall.

Sub-pulpal Wall.—When the pulp is removed, the pulpal wall disappears and the floor of the pulp chamber becomes the sub-pulpal wall.

When the Axial Wall is Removed, that wall of the cavity resulting takes the name of the wall of the pulp chamber; either mesial or distal.

Angles Named.—They take their names from the surfaces or walls forming them. Cavities when properly prepared are of a typical box or mortise shape, all the walls of which unite at definite line and point angles.

The **Angles in an Occlusal Cavity** are:

Line Angles.—Mesio-buccal, mesio-lingual, disto-buccal, disto-lingual; bucco-pulpal, linguo-pulpal, mesio-pulpal, disto-pulpal.

Point Angles.—Mesio-bucco-pulpal, disto-bucco-pulpal, mesio-linguo-pulpal, disto-linguo-pulpal.

The **Angles in Buccal or Lingual Cavities** in bicuspids and molars are:

Eight Line Angles, as follows: mesio-gingival, disto-gingival, mesio-occlusal, disto-occlusal, axio-gingival, axio-mesial, axio-occlusal, axio-distal.

Four Point Angles, as follows: axio-mesio-gingival, axio-mesio-occlusal, axio-disto-occlusal, axio-disto-gingival.

Angles in Proximo-occlusal Cavities.—There are eleven line angles and six point angles, as follows:

In the mesial or distal portion, five line angles and two point angles, viz.:

A. Line angles, bucco-gingival, linguo-gingival, bucco-axial, linguo-axial, gingivo-axial.

B. Point angles, gingivo-bucco-axial, gingivo-linguo-axial.

In the step portion, five line angles and two point angles, viz.:

C. Line angles, bucco-distal (or mesial), linguo-distal (or mesial), disto- (or mesio-) pulpal, linguo-pulpal, bucco-pulpal.

D. Point angles, disto- (or mesio-) bucco-pulpal, disto- (or mesio-) linguo-pulpal.

Also an axio-pulpal line angle, and pulpo-linguo-axial and pulpo-bucco-axial point angles may be named.

Angles in Mesial and Distal Cavities in Incisors and Cuspids.—*Six Line Angles* as follows: Labio-gingival, linguo-gingival, incisal, axio-labial, axio-lingual, axio-gingival.

Three Point Angles as follows: Axio-labio-gingival, axio-linguo-gingival, axio-incisal.

Angles in Proximo-incisal Cavities.—These cavities present the same angles as mentioned in proximal cavities in incisors and cuspids except the incisal and axio-incisal, which are missing; also in addition the *Step* will present the following, viz.:

Six Line Angles, viz., mesio- (or disto-) labial, mesio- (or disto-) lingual, pulpo-distal (or mesial), pulpo-lingual, pulpo-labial, pulpo-axial.

Two Point Angles, viz., mesio- (or disto-) pulpo-labial and mesio- (or disto-) pulpo-lingual.

Cavities may be divided for purposes of description into thirds as teeth are divided, viz., in either the horizontal, mesio-distal, or bucco-lingual plane.

It is by no means intended that the student should memorize by rote the names of the walls and angles in the various types of cavities. However, they, as well as the other terminology of cavity preparation, should be thoroughly studied so that he may become familiar with their names and uses and be enabled to properly designate them whenever necessary. The tendency in modern nomenclature is to omit the hyphens, thus transforming the hyphenated words into single terms. However, I have deemed it wise to retain them. When the student becomes thoroughly familiar with the terminology, the hyphens may be omitted if desired.

STEPS IN CAVITY PREPARATION

The proper preparation of a cavity is a systematic scientific procedure based on definite physical and mechanical laws. The technic is divided into seven stages or steps, each of which should be made as nearly perfect as possible before proceeding to the next, if ideal results are to be attained in the finished operation. Although there may be an occasional overlapping of the procedures incident to the performance of these steps, it is important that they be kept constantly in mind and that they be completed in regular sequence. These steps are as follows:

1. Establish the outline form.
2. Obtain the resistance form.
3. Obtain the retention form.
4. Obtain the convenience form.
5. Remove the remaining carious dentin.
6. Finish the enamel margin.
7. Perform the toilet of the cavity.

In very deep cavities where exposure of the pulp is feared and under other circumstances to be mentioned later, it will sometimes be advisable to place the fifth step second. The fundamental principles of correct cavity preparation are the same in all types of cavities and for whatever material that is to be used in filling them. Slight variations from the ideal forms described here are advisable or necessary for the various types of fillings and inlays. *The preparations described in this chapter are for cohesive gold. The modifications of these forms for the other materials are fully presented in their proper place in succeeding chapters.*

ESTABLISHING THE OUTLINE FORM

By Establishing the Outline Form is meant the carrying of the marginal outline to the position it will occupy on the completion of the cavity. In general, it should be carried out to areas least susceptible to decay and which will afford a good finishing margin for the filling. This will vary in different localities. The following general directions will enable the student to determine the proper location for his cavity margins under all circumstances.

Extend the margins until solid tooth structure, free from decay, is reached.

Leave no overhanging enamel margins unsupported by dentin. The enamel of the tooth is extremely brittle, owing to its histologic structure, and depends for its strength on the support which it receives from the underlying dentin.

In fissure cavities, extend the margins to include all the fissures and angular grooves. Pits and fissures are extremely liable to decay and if this rule is not followed, decay is likely to occur in that part of the fissure not included in the cavity, with a consequent undermining of the filling.

Extend the margins of cavities approaching closely to deep developmental grooves to include the grooves. This procedure is advisable for reasons of strength, since developmental grooves, located at the lines of coalescence of the developmental lobes are architecturally weak.

Unite two cavities approaching closely to each other, to prevent leaving a weak ridge of tooth structure between them.

Extend the gingival margins of cavities occurring in the gingival third of labial, buccal and lingual surfaces under the free gingiva where they will be less liable to decay.

In proximal cavities extend the labial, buccal and lingual margins into the embrasures, into areas where they will be less likely to decay; the incisal or occlusal margins beyond the contact points; and the gingival margins under the free margins of the gum. The extension of these margins, as laid down in this paragraph follows the law known as "extension for prevention" or "cutting for immunity."

Those areas at which food accumulates more readily and is less easily removed are most likely to decay. These points are pits and fissures, proximal surfaces, and the gingival third of labial and buccal surfaces These locations are more difficult to reach with the brush, lips, cheek and tongue and less subject to the scouring action of the food bolus in mastication. On the proximal surface, decay usually begins at a point slightly gingival to the contact point, consequently, cavity margins should, as a rule, be extended beyond this locality and include the contact point. Buccal, labial, and lingual surfaces are least liable to decay at or near the mesial and distal angles; hence it is well to extend the margins of cavities on these surfaces, to these locations. The same may be said of proximal surfaces and cavities occurring on them.

Extension for Prevention or Cutting for Immunity.—Proximal surfaces of the teeth are much more subject to decay than other surfaces, because food and germs accumulate more readily here, and are less easily removed. This being the case, if the margins of cavities are left in these susceptible areas, they will be much harder to keep clean, and hence decay is likely to recur readily. Recognizing this fact, it is the accepted practice to extend the margins of cavities, when they occur in these areas, by cutting away enough of the tooth substance to carry them out to locations where the food is not so liable to deposit and where they may be more readily cleansed. The food does not accumulate under the marginal gingiva so much as it does a short distance occlusally to this point, hence the reason for extension of the gingival margins. Also the secretion from the normal gingival crevice is supposed to exercise a protective influence. Food accumulates very readily and frequently remains just gingivally to the contact points of two approximating teeth, and in order to obviate the necessity of leaving the incisal or occlusal margins within this susceptible area, these margins usually are carried beyond this point down toward the incisal or occlusal surface, where they can be more readily cleansed. Buccal and lingual margins, for the same reasons, are extended out into the embrasures to relatively immune areas in the region of the axial line angles. In gingival third cavities, the gingival margins also are carried under the gingiva, and the mesial and distal margins are extended nearly to, but not beyond the axial angles, for the reasons already given.

Owing to the conditions under which operations are performed in the mouth, it is not always possible or advisable to extend cavity margins as described under the law of extension for prevention. The conditions which may justify or necessitate a modification of this operation are the following:

First.—A family history of lack of susceptibility to caries.

Second.—A personal history of similar non-susceptibility.

Third.—Presence of a period of immunity.

Fourth.—Lowered vitality from sickness, convalescence, pregnancy, adolescence and similar causes.

Fifth.—Personal habits of cleanliness.

Sixth.—Low mentality and lack of will power.

Seventh.—Perfect habits of mastication.

Eighth.—Abundance of food in the dietary requiring adequate mastication.

Ninth.—Normal, freely-flowing salivary secretion, nature's flushing agent.

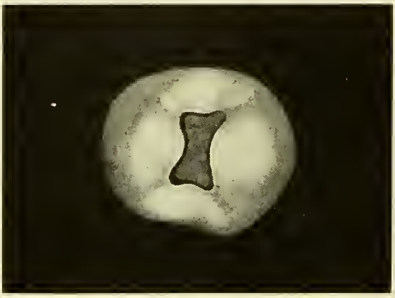


FIG. 331.—Occlusal cavity in upper bicuspid.

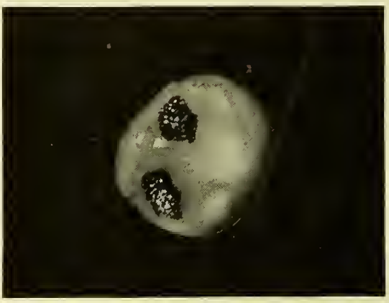


FIG. 332.—Occlusal cavities prepared and filled with gold on lower first bicuspid. The gold has not yet been polished.

Tenth.—Regularly-aligned arches.

Eleventh.—Youth and old age, these conditions frequently not admitting of extensive operations.

Cavity margins frequently may be placed in immune areas by separating the teeth and building out to full contour, thus drawing labial, buccal and lingual margins away from each other. This procedure often obviates the necessity for extensive cutting of tooth structure. Increased knowledge and more intelligent application of the principles of oral hygiene, and improvements in the qualities of modern filling materials have to some extent modified the necessity for the extensive cutting of tooth structure involved in the extension of cavity margins and the preparation of the axial and pulpal walls of cavities, as advocated in Doctor Black's time. Consequently, today there is an increasing tendency toward the advocacy of more conservative cutting on the part of the advanced thinkers and operators in the profession.

The typical outline form in the various types of cavities is regulated by the anatomical form of the surface on which the operation is to be performed and involves an intimate knowledge of the anatomy of the teeth. In the occlusal surface of upper bicuspids, extend the cavity the full length of the occlusal groove. (Fig. 331). In the occlusal surface of the lower first bicuspids, owing to the presence of a strong transverse ridge, a cavity occurring in the mesial or distal pit is usually confined to the pit and not carried across the ridge. (Figs. 332 and 333). In lower second bicuspids the form will be somewhat crescentic or triangular, depending on the shape of the occlusal groove. (Fig. 334.) In the occlusal surface of upper molars if the cavity is located in the central fossa, include as much of the buccal and mesial grooves as is necessary to establish good

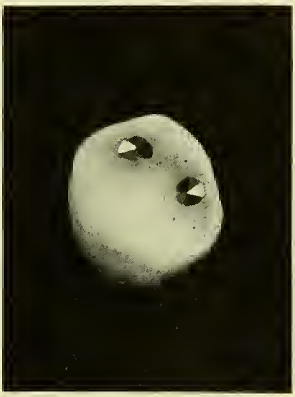


Fig. 333.—Same as Fig. 330, with the fillings finished and polished.

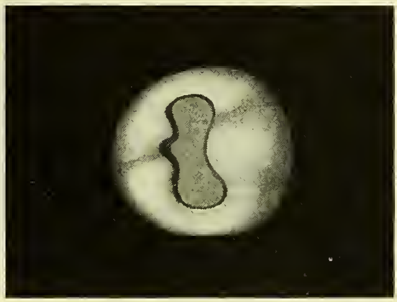


Fig. 334.—Prepared occlusal cavity in lower second bicuspid.

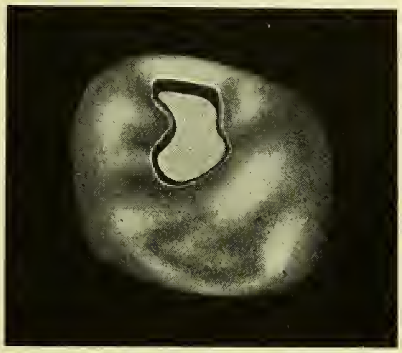


Fig. 335.—Prepared cavity in the central fossa of an upper molar. A-typical form.

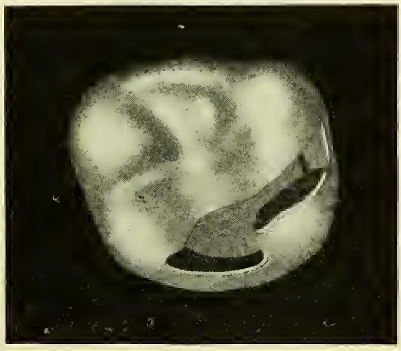


Fig. 336.—Prepared cavity in the distal fossa of an upper molar, extending full length of the lingual groove.

finishing margins. (Fig. 335.) In the distal fossa the cavity usually is oblong in shape and may sometimes be confined to the occlusal surface; in many instances, however, the lingual groove is deeply fissured, and it is then necessary to extend full length of this groove and on to the lingual surface. (Fig. 336.) If cavities involve both the central and distal fossae and approach each other very closely, the oblique ridge should be removed and the cavities united. Often the best mode of deciding as to the advisability of uniting the two cavities is to prepare them separately, when the judgment of the operator will then dictate for or against the uniting of the cavities. In three-cusped third molars there will be no distal fossa, consequently, the typical-shaped cavity will involve the central fossa, with just enough of the mesial, buccal and distal grooves

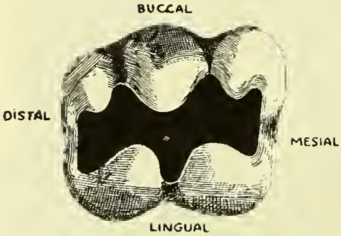


FIG. 337.—Cavity on the occlusal surface of a lower first molar.

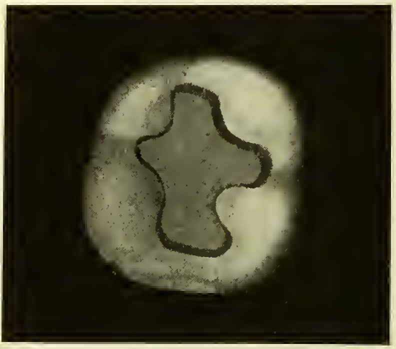


FIG. 338.—Cavity in lower second molar.

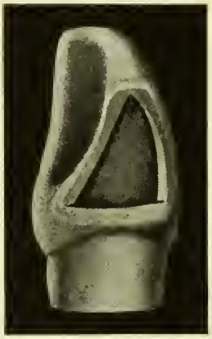


FIG. 339.—Prepared cavity on the proximal surface of an incisor.

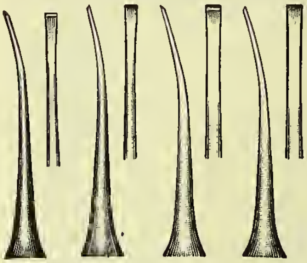


FIG. 340.—Wedelstaedt chisels No. 41, 42, 43 and 44.

to obtain good finishing margins, the resultant form being more or less triangular in shape.

In the occlusal surface of lower first molars the cavity will include a portion of the five grooves found on that surface, viz., buccal, disto-buccal, mesial, distal and lingual, (Fig. 337), while in the lower second molar the resultant form will be crucial in shape. (Fig. 338.) The form in the lower third molar will resemble that described for the first or second molars, depending on the form of the tooth. A cavity in the proximal surface of any of the anterior teeth, upper or lower, will present a triangular form, with a straight gingival margin or one following the curvature of the interdental papilla. The gingival margin should join the labial and lingual margins at rounded angles, while the two latter margins will converge to complete the third rounded apex of the triangular form. (Fig. 339.)

TECHNIC AND INSTRUMENTATION

The techniques and instrumentations described in this and the succeeding chapters are presented chiefly with the desire to further systematize operative procedure. In no sense is it the intention of the author to arbitrarily advocate them to the exclusion of others. This would interfere with individuality and the personal equation in teaching—qualities which are very desirable. However, there should be a unification and systematization of the teaching by the entire Operative Staff. Therefore, other instruments or modifications of those mentioned in this work, may be substituted, if deemed desirable, without in any manner interfering with the general scheme of technical procedure advocated by the author.

The technic for obtaining outline form is herewith briefly given. It is more fully described in the following chapter.

Pit and Fissure Cavities.—Class I. If small, open and extend full length of the fissure with a fissure bur number 57, 58, or 557. In using, extend the point of the bur under the enamel and cut from within, outward. Small pits frequently may be better opened at the beginning with the round bur, number ½. If necessary to extend the margins much, an inverted cone bur, number 33½, will first undermine the underlying dentin, when the enamel may be removed readily with hoes 8-3-6, 8-3-12, chisel 15 or Wedelstaedt number 41 or 42, depending on size and location of the cavity. Fig. 340. In large cavities of this class, first chisel away overhanging enamel margins with chisel number 15 or Wedelstaedt number 41 or 42, then use the inverted cone bur for extension into solid dentin, after which use the chisel or hoes 8-3-6, or 8-3-12 again, for removal of any further enamel.

Smooth Surface Cavities.—First break down all unsupported enamel with the chisels, number 15 or Wedelstaedt's number 40 and 41, hoes 8-3-6, 8-3-12, or hatchet number 8-3-12, depending on the size and location of the cavity, cutting in the direction of the length of the enamel rods. Avoid shock by refraining from cutting too large amounts at each thrust or blow. Then, if necessary to extend margins further, first undermine the underlying dentin with the inverted cone bur number 33½, when the enamel may be removed readily by means of the previously mentioned instruments, enamel hatchets 15-8-12, right and left, or gingival margin trimmers 12-(95)-8-12, and 12-(80)-8-12, depending on the location. For instruments see Chapter VII.

OBTAINING RESISTANCE FORM

By resistance form is meant the so shaping of the walls of the cavity that they may be enabled best to withstand the stress brought to bear on the filling during the act of mastication.

Doctor G. V. Black perfected an instrument invented by Patrick and Dennis, known as the gnathodynamometer for measuring the strength of the bite. In a tabulation of one thousand persons examined with this machine, the average force exerted was one hundred and seventy-one pounds on the molars, less on the bicuspids, and still less on the incisors. In an examination of fifty persons ranging in age from four and one-half to forty-five years, it was found that the strength of the bite on incisors ranged from thirty to one hundred and seventy-five pounds, while on the molars there was a variation of from forty-five to two hundred and seventy pounds. Since Doctor Black's time improvements have been made in the gnathodynamometer by other inventors. Another appliance known as the phagodynamometer has been utilized to test the force required for crushing food stuffs. With this instrument, beef steak is shown to require a force of from forty to eighty pounds, stick candy ninety to one hundred and twenty pounds, gum drops two hundred and fifty pounds, some bread crusts three hundred and fifty pounds.

Pulpless teeth usually are not subjected to the same amount of strest as vital teeth. Individuals seem naturally to avoid subjecting them os excessive stress; hence ideal resistance form in these teeth may occasionally be not so important as in normal teeth.

Mortise Forms.—In resistance form the general shape of the cavity is the box or mortise form. In this form all of the walls of the mortise are on plane or straight lines, joining at definite line and point angles. This general idea is followed out in mechanical procedures in other callings, hence its adoption in cavity preparation. The use of this form is advocated for several reasons, viz.:

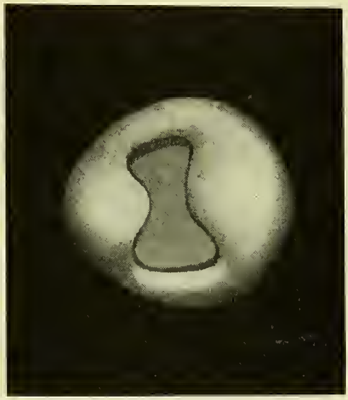


FIG. 341.—Class I cavity on an upper bicuspid.

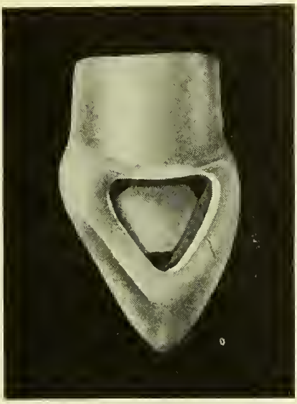


FIG. 342.—Class III cavity (proximal).

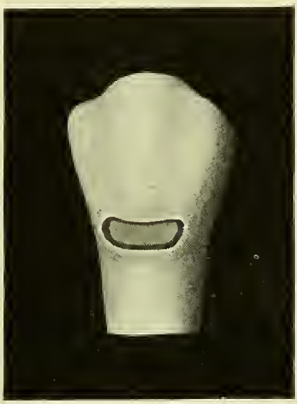


FIG. 343.—Class V cavity on a lower bicuspid.

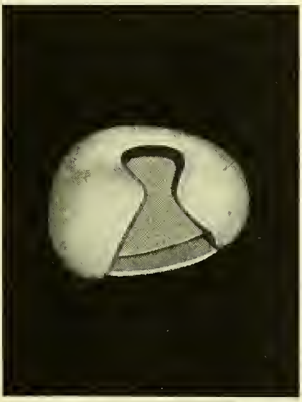


FIG. 344.—Proximo-occlusal cavity on a bicuspid. Class II.

First.—The seat for the filling is thus placed at a distinct right angle to the line of stress, a condition which is considered ideal in all construction work.

Second.—Gold and other filling materials are most readily adapted against plane surfaces.

Third.—The tendency to splitting away of the buccal and lingual cuspal elements in bicuspids and molars is thus greatly diminished, the filling otherwise acting as a wedge.

Fourth.—The cavity is thus rendered more accessible to view and further operative procedures.

Fifth.—The properly-wedged filling is thus most securely gripped in place by the normal resilience or elasticity of the dentin of opposing parallel walls.

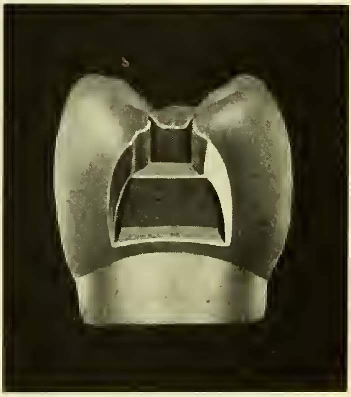


FIG. 345.—Proximo-occlusal cavity on a molar. Class II.

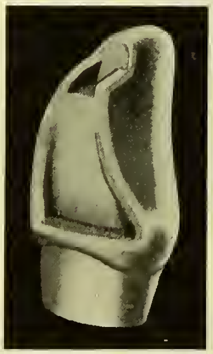


FIG. 346.—Proximo-incisal cavity on a central incisor. Class IV.

The Mortise Forms are shown in Figs. 329 and 330, viz.: the simple mortise on one surface, A; the simple dovetail mortise on one surface, B; the simple mortise involving two surfaces, C; the simple dovetail mortise involving two surfaces, D; the auxiliary, compound, or double mortise, E; the auxiliary or compound dovetail mortise, F.

In the shaping of simple cavities (classes I, III, and V) adopt the simple mortise or box form, or some modification of it. (Figs. 341, 342 and 343.) In proximo-occlusal cavities, (Class II), use the double, compound, or auxiliary mortise form (step form). (Figs. 344 and 345.) In proximo-occlusal cavities on lower first bicuspids, where the occlusal decay does not extend across the transverse ridge, the simple mortise form involving two surfaces may occasionally be used. In proximo-incisal cavities (class IV), use the double, compound or auxiliary mortise form, either in the shape of an incisal step or a lingual step form. (Figs. 346, 347 and 348.)

The Instruments used for obtaining the box or mortise form are those types which cut plane surfaces, such as fissure burs, hoe and hatchet excavators and enamel hatchets. Round burs, spoons and instruments which cut concave surfaces have no place in the preparation of resistance form. In the majority of cases, the bulk of the work is best done with hand instruments. The instrumentation and technic for accomplishing the various steps in cavity preparation are briefly given in this chapter. Complete details of the procedures are described in the following one.

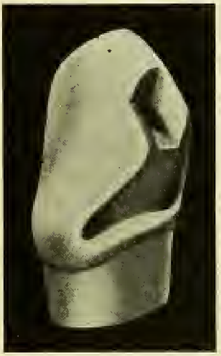


FIG. 347.—Proximo-incisal cavity on the distal surface of a cuspid. Class IV.

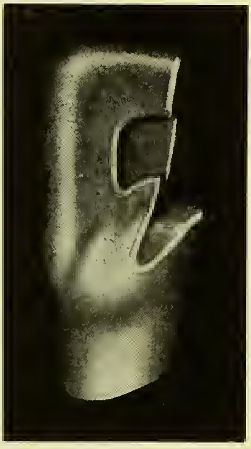


FIG. 348.—Proximo-incisal cavity on a lateral incisor, showing lingual step form. Class IV.

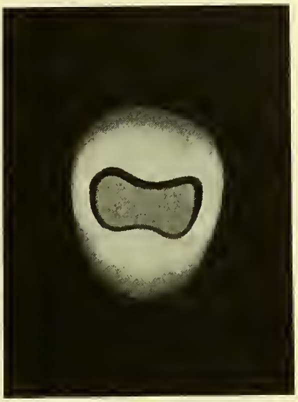


FIG. 349.—Class I cavity.

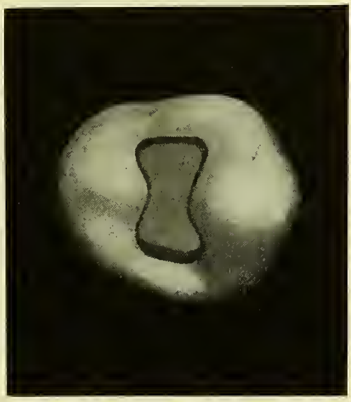


FIG. 350.—Class I cavity.

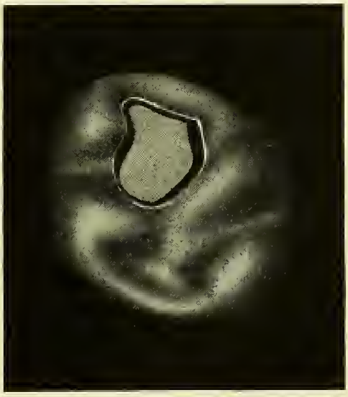


FIG. 351.—Class I cavity, extensive decay.

Technic for resistance form in Pit and Fissure and Gingival Third Cavities, Classes I and V.

With burs, hatchet or hoe excavators flatten the floor in pit and fissure cavities or curve the axial wall to follow the convexity of the wall of the underlying pulp chamber in gingival third cavities. Then true up the lateral walls until they are plane surfaces, parallel with each other and joining with the pulpal or axial wall (the seat) at definite line angles. (Figs. 349 to 354.) In class I cavities fissure burs 56, 57, 58 and 557, hoe 8-3-12 and hatchet 10-3-12 are best adapted. Hoes 8-3-12 and 8-3-23 and hatchets 8-3-23 are recommended for accomplishing the same results in class V cavities.

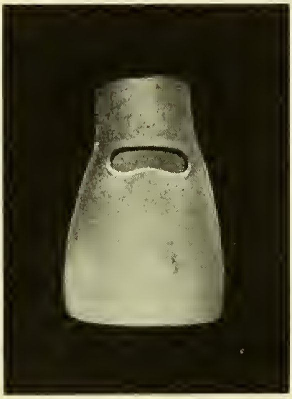


FIG. 352.—Class V cavity.

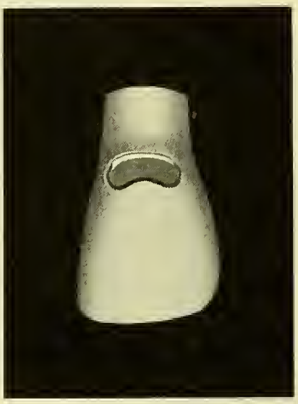


FIG. 353.—Class V cavity.

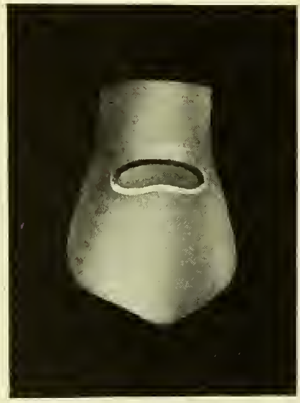


FIG. 354.—Class V cavity.

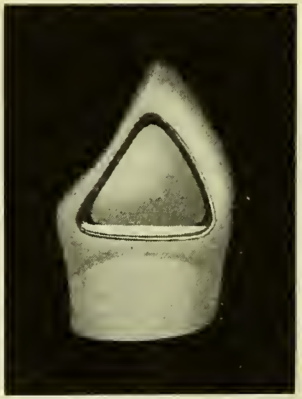


FIG. 355.—Class III cavity.

Technic for resistance form in Cavities in the Proximal surfaces of Incisors and Cuspids not involving the angle. Class III.

Use inverted cone bur 33½, hoe 4-1-23 and Woodbury-Crandall angle formers 10-(80)-4-6, right and left (specials). Flatten the gingival and axial walls, making a definite line angle at their junction. The axial wall should follow the convexity of the underlying pulp chamber in a labio-lingual direction. Bring the axial, gingival, labial and lingual walls together at two definite point angles (labio-gingivo-axial and linguo-gingivo-axial). Make definite line angles at the junction of the labial and lingual walls with the axial (labio-axial and lingo-axial). Join the labial and lingual walls together at a definite point-angle at the incisal portion of the cavity (incisal angle), the resultant form being triangular in shape, with three definite point angles. (Figs. 355 and 356.) For instruments see Chapter VII.

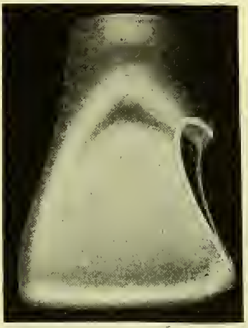


FIG. 356.—Class III cavity, lingual view.

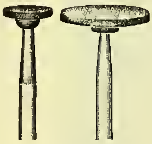


FIG. 357.—Carborundum wheels No. 48 and 11.

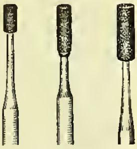


FIG. 358.—Carborundum points No. 32, 31 and 36.

Technic for resistance form in cavities of the above character which involve the angle. Class IV.

Incisal Step Form.—The preparation of the proximal portion of the cavity is similar to that described for Class III. With carborundum stone number 11 S. S. W. (Fig. 357) grind the enamel off of the cutting edge over into the middle lobe of the tooth, until the dentin is exposed. The labial and lingual margins of the cavity first should have been extended over as far as conditions of strength and removal of decay demand, but not in too close proximity to the developmental groove. The angle is cut away the same distance. Then with fissure bur 33½ remove the dentin between the enamel plates, after which remove with stone number 31 S. S. W. (Fig. 358) a portion of the lingual enamel plate, leaving the labial plate untouched as far as possible, to avoid exposure of gold. Now, with fissure bur 557 cut a groove across the step thus formed, in between the labial and lingual enamel plates, into the dentin, which has been exposed by the bur 33½ and the carborundum stone. Then deepen the groove further, continuing in this manner until the step is of sufficient size and depth to admit of the necessary strength for resistance and to allow of a sufficient body of gold to withstand all strain. (Figs. 359 and 360.)

Lingual Step Form.—This form is used where the tooth is too thin labio-lingually to warrant the incisal step. With an inverted cone bur number 33½ cut an auxiliary mortise form or step on the lingual surface of the tooth. With hoe 8-3-12 the floor of this step is made flat and the lateral walls plane surfaces, joining the floor at definite line angles. Avoid exposing the pulp. (See Fig. 348.)

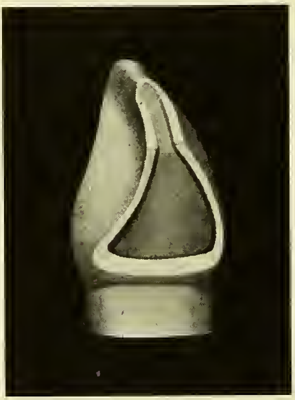


Fig. 359.—Class IV cavity in central incisor.

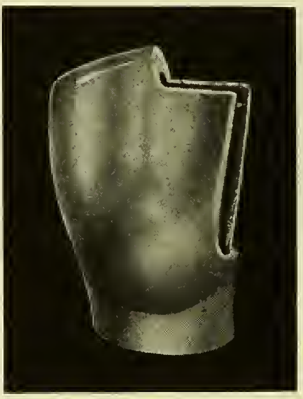


Fig. 360.—Lingual view of class IV cavity in central incisor.

Technic for resistance form in Cavities on Proximal Surfaces of Bicuspids and Molars. Class II.

The cavity herewith described is the form advocated by Black and which has been used by the profession for many years. It is described here in order that it may still be used by those who prefer to continue its adoption. In the succeeding chapter an entirely new form of Class II cavity is presented, which has many advantages over the old form and which I advocate.

In the Black form the cavity is extended onto the occlusal surface in the form of a step, it frequently being necessary to break down the undecayed marginal ridge. With inverted cone bur 33½ inserted into the occlusal pit or fossa, drill an opening through the dentin toward the proximal cavity until the area of decay is reached. Then with enamel hatchets 10-6-12 or 15-8-12 or Wedelstaedt chisels 40 and 41 cleave away the enamel of the marginal ridge and enlarge the opening until free access to the proximal decay is gained.

After removal of the marginal ridge, open the proximal cavity and extend it in the form of a step the full length of the occlusal groove (bicuspids), or to include the central or distal fossa (molars). Flatten the gingival wall (the seat), make the buccal and lingual walls parallel with each other and joining the gingival wall at definite line angles. Make a definite line angle at the junction of the gingival and axial walls (gingivo-axial) and definite point angles (bucco-gingivo-axial and linguo-gingivo-axial), at the buccal and lingual terminations of this line. Flatten the top of the step, the pulpal wall, and cut that portion of the cavity, as well as the proximal part, to the box form with its line and point angles. (Figs. 361 and 362.) For preparation of the occlusal step the same instruments previously mentioned for obtaining resistance form in Class I cavities are used. Enamel hatchets 10-6-12 and 15-8-12 rights and lefts are valuable for cutting and scraping the walls of the proximal portion to plane surfaces and for accentuating the line angles.

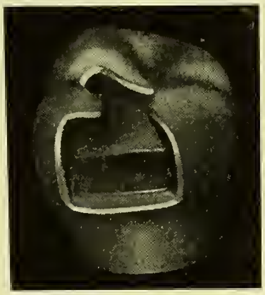


Fig. 361.—Class II cavity on a molar.

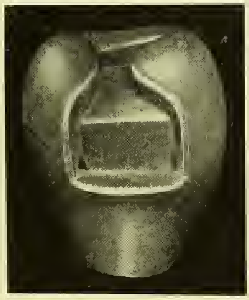


Fig. 362.—Class II cavity on a bicuspid.

RETENTION FORM

By retention form is meant the so shaping of a cavity that the filling may best resist displacement through tipping or lifting stress. During the preparation of the resistance form this frequently has been provided for to some extent, though not always, nor sufficiently.

If the depth of the cavity is sufficient and gold or other filling materials are thoroughly condensed, no extra retention form is needed, the filling being retained by its perfect contact with and the grip of the resilient parallel dentinal lateral walls of the cavity. However, in some cases, additional retention may be provided for by dovetailing the mortise form. (Figs. 328 and 329.) For this purpose, inverted cone burs and hoe and hatchet excavators are employed. For detailed instrumentation see the succeeding chapter. Only general instructions are given here.

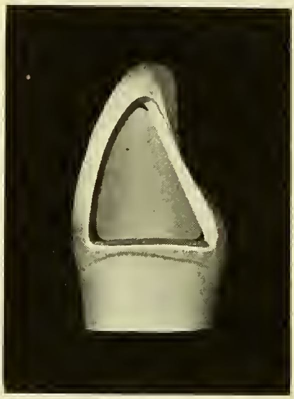


Fig. 363.—Class III cavity on incisor.

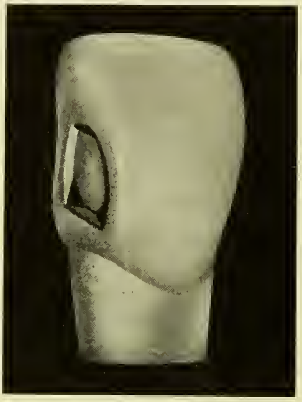


Fig. 364.—Class III cavity on incisor.

Technic for retention form in Proximal Cavities on Incisors and Cuspids not involving the angle. Class III.

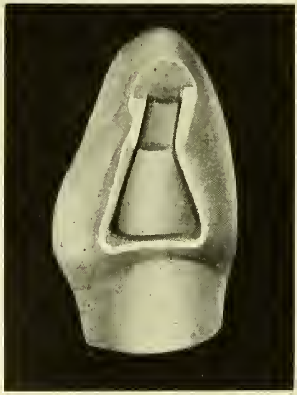


Fig. 365.—Class IV cavity on central incisor.

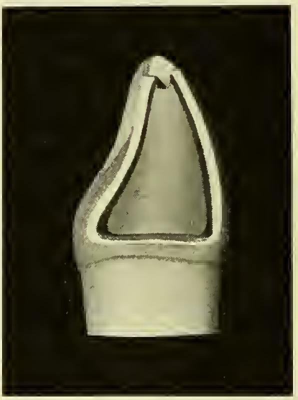


Fig. 366.—Class IV cavity on central incisor.

The method of establishing the mortise form with its line and point angles has been described under resistance form. For retention, all that is now necessary is still further to accentuate the three point angles (labio-gingivo-axial, linguo-gingivo-axial and incisal). A No. 33½ inverted cone bur is used on the gingival point angles, while hatchet 4-1-23 or S. S. W. 66 or 70 are better adapted to the incisal angle. (Figs. 363 and 364.)

Technic for retention form in Proximal Cavities on Incisors and Cuspids involving the Angle. Class IV.

In the incisal step form the entire step, which has been given a flat floor, may be slightly dovetailed on its labial or lingual wall and slightly deepened at its extremity by means of a 33½ inverted cone bur if deemed desirable or necessary. (Figs. 365, 366 and 367.) In the lingual step form the step may be slightly dovetailed throughout and its two point angles made more acute by means of the same bur. (Fig. 348.)

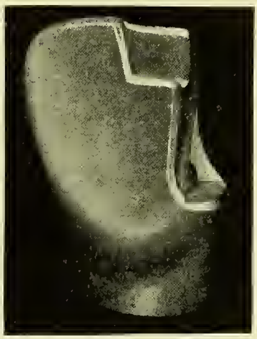


Fig. 367.—Class IV cavity on central incisor. Lingual view.

The lingual step should be placed as near the incisal surface as conditions of strength will admit in order to resist the leverage and tipping stress of the forces of mastication. However, it should not be placed so close as to weaken the incisal portion.

Technic for retention form in Proximo-occlusal cavities on Biscupids and Molars. Class II.

Retention is provided by adopting the compound dovetail mortise form (Fig. 361), the step portion of which being wider bucco-lingually at its extremity, locks the filling into place. See Chapter XIII.

CONVENIENCE FORM

By convenience form is meant the shaping of the cavity in such a manner that it may be most conveniently seen, approached, and filled with instruments. Slight extension of mesial, buccal or lingual cavity margins for this purpose is occasionally admissible. The extension of labial margins is prohibited for esthetic reasons. In addition to extension of margins, deepening, or making more acute, one or more point angles, for convenience in starting gold fillings is often advisable. These are known as convenience angles or points. Often this is unnecessary in Class I and Class V cavities, though the accentuation of one or more point angles may be resorted to, if desired. Deepening of both of the gingival point angles in Classes II and III is usually advisable for starting gold. The same holds true for the point angles at the extremity of the step in Classes II and IV cavities. Deepening of the incisal angle in Class III is necessary for retention of the filling as well as for convenience form. Convenience angles may be prepared with inverted cone bur 33½, placing the bur in the point angle and cutting more at the expense of the lateral walls than of the floor of the cavity. In deepening gingival point angles, do so more at the expense of the axial, labial, buccal and lingual walls, than of the gingival wall. Place the blade of the instrument in the point angle, and after slightly deepening it at the expense of the gingival wall, cut along the line angle uniting the labial, buccal and lingual wall (as the case may be) with the axial wall, for a distance of about one-fourth the length of the line angle, thus forming a slight groove, which gradually disappears at its termination. Gingival point angles often may be better prepared with gingival margin trimmers or the Woodbury-Crandall instruments 10-80-4-6 right and left. For making the incisal retention form in proximal cavities in incisors and cuspids use the hatchet 4-1-23 or S. S. W. 66 or 70, placing its blade in the point angle, and cutting at the expense of the labial and lingual walls, as well as deepening the angle toward the incisal. Never use a bur for this purpose.

REMOVAL OF DECAY

The next step to be considered is the removal of the decay. Although during the performance of the previous steps most of the carious matter will be removed, it should usually be done, not with that idea primarily in view, as is so frequently the case with inexperienced operators, but it should be merely incidental to the operation of placing the cavity margins in their proper location and the formation of the internal parts of the cavity. On completion of these procedures, the cavity should now be thoroughly inspected for any remaining traces of decay which should be completely removed.

During the progress of caries, decalcification by lactic acid precedes invasion by micro-organisms. This being the case, the deepest portion of the dentin may have been partially decalcified though not necessarily decayed and "infected." Discoloration also frequently precedes the process of decay. Therefore, the dentist is in some instances justified in leaving minute portions of *discolored* or *partially decalcified* hard dentin on the walls of cavities to avoid possible exposure of the pulp. In such cases the cavity should be thoroughly sterilized. However, in every instance it is necessary to remove the smallest trace of infected, decayed and softened dentin, to prevent the continuance of decay under the filling and to avoid irritation and inflammation of the pulp.

In large, deep cavities where pulp exposure is feared and in very sensitive cavities, especially Class V, removal of decay may often be made the second step to advantage. Removal of decay at whatever stage of the operation is usually best accomplished with spoon excavators 13-8-12 or 8-6-12. The method of its removal depends on the character of the tissue, the size and location of the cavity and the sensitivity of the dentin.

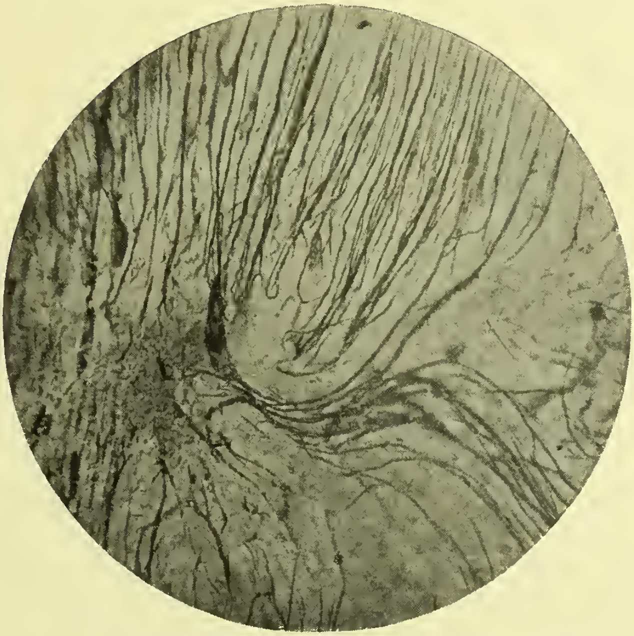


FIG. 368.—Dentin of crown showing convoluted tubules. Low power. (Courtesy of Dr. John B. Stein.)

Shallow Cavities on Exposed Surfaces.—The dentin usually is very sensitive in these cavities. Remove it with spoon excavators 8-6-12 right and left. Do not temporize, but make decisive cuts, removing the decayed matter as quickly and in as large bulk as possible.

Large Cavities with Soft Decay.—Use spoon excavators 13-8-12, first flaking up the decay around the margins and then peeling it off in layers, avoiding pressure.

Hard, Dark Brown and Black Decay.—Use the spoon excavators. Burs should never be used for removal of decay, on account of endangering the recessional lines of the pulp or of producing pulp exposure.

Dentin usually is most sensitive at the dento-enamel junction. Two reasons are given for this, viz.:

First.—A nerve always manifests the greatest sensitivity at its termination. The dentinal fibrillae, though not true nerve tissue, have practically the same functions.

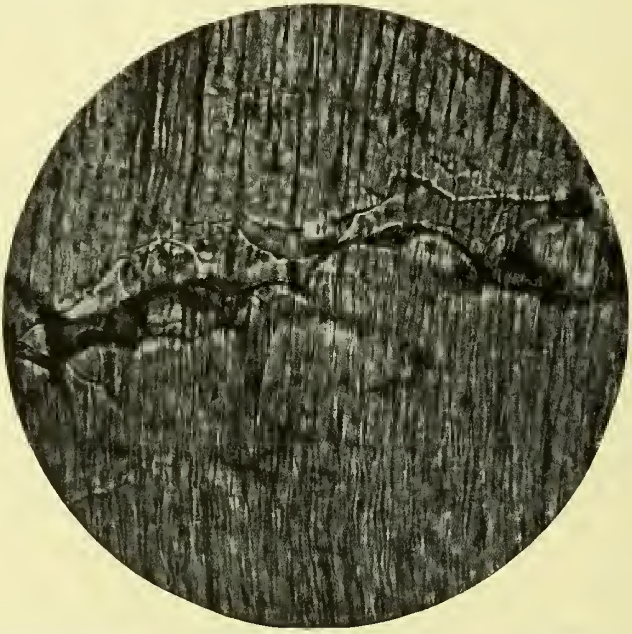


Fig. 369.—Dentin of crown showing interglobular spaces. High power. (Courtesy of Dr. John B. Stein.)

Second.—On the surface of the dentin there is an extensive network or anastomosis of the dentinal fibrillae, with the result that, when a few fibrils are touched or cut, the sensation is transmitted not only by these, but is reflected along the anastomotic network to other fibrils, thus making a greater impression on the nerve fibers in the pulp, from which it is transmitted with redoubled force to the receptive centers in the brain. The latter is the largely accepted theory. (Figs. 368 and 369.)

FINISHING THE ENAMEL MARGINS

The enamel is composed of numerous layers of pentagonal or hexagonal shaped rods, the enamel rods, each rod being made up of globules placed end to end. The globules are united very firmly together, while each individual rod is joined less firmly to its neighbor with cementing substance. The enamel is the hardest tissue in the body and very resistant to cutting instruments. If, however, the underlying dentin be first removed, either by decay or with cutting instruments, the enamel rods may be chipped away readily or cleaved by chisels in thin layers, in the direction of their length.

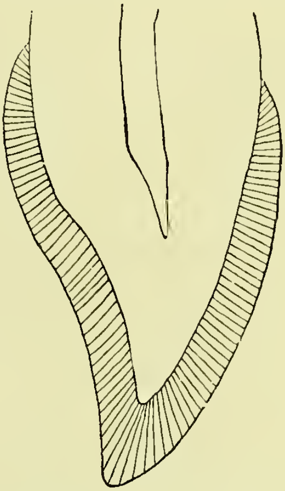


FIG. 370.—Sketch showing inclination of the enamel rods on anterior teeth.

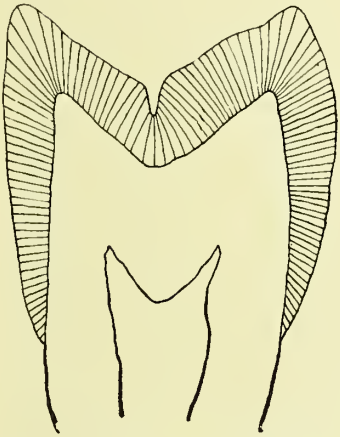


FIG. 371.—Sketch showing inclination of enamel rods on bicuspids.

On plane surfaces the enamel rods are placed perpendicularly to the dentin; on concave surfaces their outer ends radiate toward the center of the concavity, fossa or pit, while on convex surfaces they radiate away from each other.

The inclination of the rods on the various surfaces of centrals, laterals and cuspids is as follows (Fig. 370): On the incisal surfaces the rods are perpendicular to the long axis of the teeth. At the incisal angles of these teeth the rods on the incisal and proximal surfaces incline toward the angles. On axial surfaces, they are more or less horizontal to the long axis of the tooth, radiating markedly to the gingival and to the incisal as these areas are approached—the more convex the surface, the greater the radiation of the rods. At the marginal ridges the direction of the rods is uncertain, though their tendency is to incline toward the ridge.

The direction of the rods on bicuspids and molars (Figs. 371 and 372) is as follows: At pits and fissures the outer ends approach the pit or fissure, but incline more and more to the perpendicular as we travel away from these locations. At the points of the cusps the rods on occlusal and axial surfaces incline toward the cusp. On axial surfaces they lie more or less horizontal to the long axis of the tooth, radiating more and more to the occlusal and to the gingival as these regions are approached. At marginal ridges the rods incline toward the occlusal or proximal surfaces; toward the ridge on occlusal surfaces.

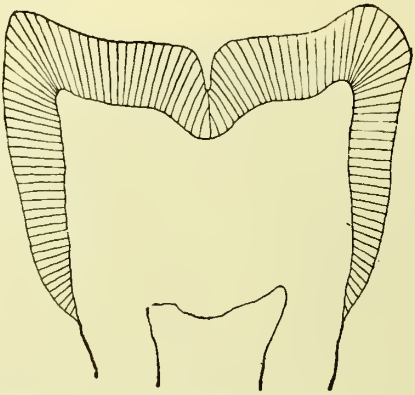


Fig. 372.—Sketch showing inclination of enamel rods on molars.

In the preparation of cavity margins the cutting should follow the general direction of the enamel rods in the different localities, the rods being chiseled away along their lines of cleavage. The cleavage should include the entire thickness of the enamel. In every instance all unsupported rods should be removed, the enamel wall consisting of full length rods supported by dentin. In small pit and fissure cavities, owing to the inclination of the rods, the enamel wall should be made continuous and on the same plane with the dentin wall, an increasing outward inclination being given it with the increase in size of the cavity and the approach of its margins toward the point of the cusps. In proximal cavities a marked bevel is indicated at the gingival margin, while on incisal margins, the incisal inclination of the enamel wall will depend on the proximity of these margins to the angle and the convexity of the surface, the rods radiating to a greater degree at the angles than in the center, and on distal convex surfaces, than on mesial surfaces.

The inclination of the enamel wall will be regulated largely by the location of the cavity, direction of the enamel rods, strength of the bite, friability of the enamel, and edge strength of the filling material.

It formerly was thought that the variation in hardness of different specimens of enamel was due to a difference in the proportion of lime salts. It is now attributed to the amount of interlacing of the rods; the greater amount of this condition being present, the harder and more resistant to cutting instruments the specimen. In the very hard varieties the minute structure presents a gnarled appearance, particularly in the deeper layers, and somewhat simulates that of a pine knot. (Figs. 373 and 374.)

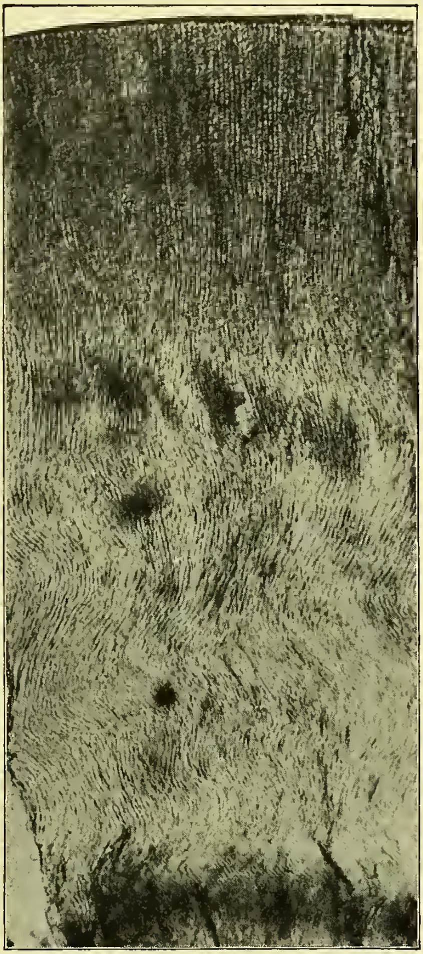


FIG. 373.—Enamel showing straight, parallel rods. (From G. V. Black's Operative Dentistry.)

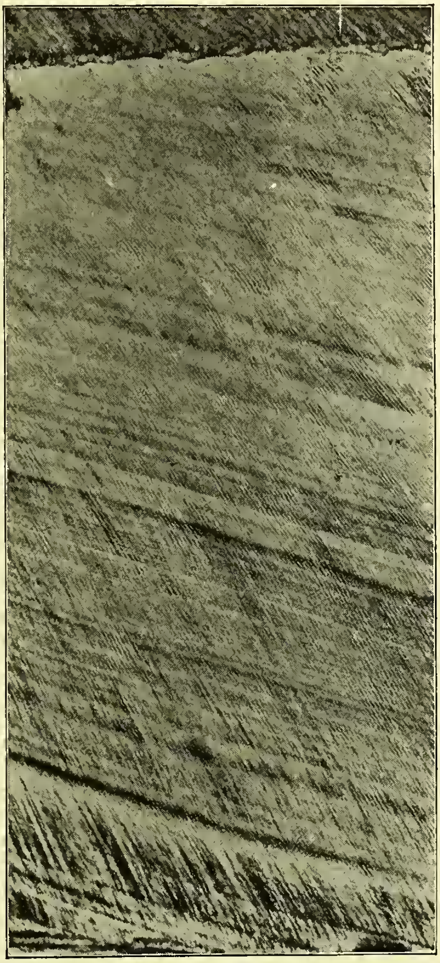


FIG. 374.—Curled or gnarled enamel. (From G. V. Black's Operative Dentistry.)

If the enamel walls have been trimmed to follow the lines of cleavage in the various localities, little additional bevel is necessary. Various authorities in the past have taught that the outer one-third of the enamel should be given a definite and distinct supplementary bevel of about three centigrades. In many instances this results in too marked a bevel, producing a thin and jagged edge to the filling. Following the cleavage and trimming of the enamel, it should then be planed to extreme smoothness. For cleaving, bevelling and planing enamel margins, chisels of razor-like sharpness are indicated in the majority of cases; enamel hatchets, gingival margin trimmers, S. S. W. hard bits numbers 13 and 14 and Wedelstaedt chisels 40 and 41 being preferred. Polishing strips, discs and stones should never be used in the preparation of the cavo-surface angle for gold fillings.

Cavity outlines should be on regular curves or definite straight lines for esthetic reasons. When two margins join each other at an angle, the angle should be slightly rounded, being careful to leave the definite line angle in the underlying dentin. The bevel should always be definite, well defined and on straight lines from its deepest point to the surface, not curved.

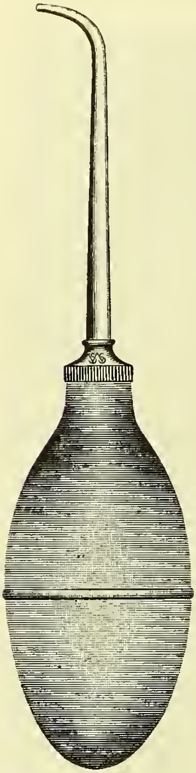


FIG. 375.—Student's chip-blower.

TOILET OF THE CAVITY

The manipulations incident to performance of the toilet of the cavity may be outlined as follows:

First.—Remove all debris with warm air from the chip blower or compressed air apparatus. (Fig. 375.)

Second.—Inspect the cavity for any remaining decay, which should be removed.

Third.—Swab the walls thoroughly with absolute alcohol, then with dry cotton or spunk, thus loosening any further debris; then use the air syringe again, thoroughly drying the walls.

Fourth.—If sterilizing agents are, or have been used, freshen up the surface with a sterile instrument, swab the walls with alcohol, evaporate and dry again with cotton before filling.

Fifth.—If, after completion of the cavity preparation, a dressing is sealed in until the next sitting, freshen up the walls again with a sterile instrument, swab with absolute alcohol and dry before insertion of the filling.

Sixth.—All fillings should be placed against clean, freshly-cut walls which have been swabbed with absolute alcohol.

CHAPTER XII

A STANDARDIZED SYSTEM OF INSTRUMENTATION FOR CAVITY PREPARATION—FUNDAMENTAL PRINCIPLES—INSTRUMENTATION FOR CLASS I CAVITIES

No apologies are offered for presenting a further and more completely developed standardization of the system of operative procedure presented to the profession by Doctor G. V. Black. The chief value of Doctor Black's work has been that he developed a definite system for teachers, students and practitioners, whereby the individual ideas and random, unscientific thoughts and teachings of those who preceded him were investigated and correlated, through scientific research, and placed on a rational plane, based on accepted physical, mechanical and biological laws.

It is claimed by some that such a standardization is likely to interfere with the development of initiative and to destroy the individuality of the student. It is not my intention to do so. Individualism is frequently not an intellectual, but an emotional problem. Often it is not a problem of logic and sound reasoning, but the result of an emotional reaction. The conflict between standardization and individualism which would destroy standardization is as old as humanity and will continue as long as the world lasts. Individualism is frequently unwilling to abide by accepted and fixed laws or principles, but has a desire to adopt personal ideas or new and untried procedures which may interfere with the progress of a profession, or a race, or of the individual himself. In rare instances, individualism, backed by unusual qualities of mind and exceptional genius for leadership, may lead to new discoveries or to revolution in science, commerce or government. For the average human being it often leads to confusion, impeded development and mediocrity.

The system herewith presented is intended for use among groups or classes of students and its adoption results in unanimity of teaching by the various members of the staff. The teaching of individual ideas and methods by different instructors leads to confusion and misconception in the minds of the students and impedes progress. The selection of instruments and the systematic procedures included in the technic are the result of intensive study and extended research. They may be modified to suit the needs of teachers and students in any school. Their adoption has resulted in a marked improvement and unanimity of teaching and a very noticeable increase in technical facility and development of productive power in groups of students in the operative clinic. Its adoption in a number of the schools has enabled classes of students to perform a larger volume of work of a much higher quality than similar groups were enabled to produce before the system was perfected. Under this system entire graduating classes have successfully passed the operative clinical examinations before State Boards of Dental Examiners, a result which had not before been attained.

This system is a standardization of general basic principles. In the latter part of the course and after graduation, the student is encouraged to modify it, depending on his intellectual capacity for improvement and the development of his personality and individuality. It is based on a systematic study of instruments and instrumentation, chair, operating and finger positions, a definite method of instrument case-placement and arrangement of the operating table, as well as on a thorough knowledge of tooth form and structure and the clinical features of pathologic processes affecting these tissues. The fundamental principles of these subjects have been discussed in previous pages. It is believed that their correlation and organization into a systematized technic will be a distinct contribution toward the advancement of Operative Dentistry, the development of a better operative procedure and greater productive power among operative dentists.

Each of the instruments in the selected set herewith presented has a definite function to perform in the preparation of the cavity and, when used for that purpose, saves time, prevents haphazard operating and increases efficiency. The student should learn to thoroughly master this set, when he will find that frequent changes from one instrument to another without definite reasons leads to bungling and slovenly work and great loss of time. In general the blades are smaller than many of those originally recommended in the Black set. Modern methods of instrumentation, increased knowledge of oral hygiene, practice of preventive dentistry and closer supervision of patients have tended to reduce the necessity for many of the large size cutting instruments advocated in Doctor Black's time. Large instruments are indicated only in exceptional cases and, even in these, the smaller ones will frequently serve the purpose.

Regardless of the preceding statements it must be stressed that it is not the intention of the author to arbitrarily attempt to force upon teachers the use of the exact instruments mentioned in these discussions. Undoubtedly there will be a number of teachers who will prefer the use of modifications or substitutes for some of those recommended. To this there can be no objection whatever, provided the modifications or substitutions will perform similar work to the satisfaction of the Operative Staff of the School in which the changes are made. The author is merely arguing for an exact technic, a systematization of operative procedures and unification of the teaching.

FUNDAMENTAL PRINCIPLES

As previously stated, cavities may be classified from the standpoint of their treatment into five groups or classes. These groups present characteristics which demand different treatment and instrumentation for the cavities in each class, although the steps and fundamental procedures in their preparation are the same as has been previously outlined.

Cavity Classification.—Class I. Cavities beginning in structural defects in pits and fissures.

Class II. Cavities in the proximal surfaces of bicuspids and molars.

Class III. Cavities in the proximal surfaces of incisors and cuspids not requiring the removal of the incisal angle.

Class IV. Cavities in the proximal surfaces of incisors and cuspids which require the removal of the incisal angle.

Class V. Cavities in the gingival third of labial, buccal and lingual surfaces.

In the preparation of any of these five classes of cavities, the steps in cavity preparation should be constantly borne in mind and should be performed in orderly sequence. These steps, as previously determined, consist of (1) obtaining outline form, (2) resistance form, (3) retention form, (4) convenience form, (5) removal of any remaining decay, (6) finishing the enamel wall and (7) performing the toilet of the cavity. Frequently, it will be impossible to definitely separate each of these procedures. For instance, obtaining the resistance and retention form is usually accomplished at the same time and with the same instruments, and in smaller cavities the removal of decay is usually automatically accomplished incidentally to the preparation of the resistance and retention form. However, in spite of the frequent overlapping of the various steps, they should be constantly in the mind of the operator throughout the procedures incident to the completion of the operation.

Instrument Selection.—In the performance of each step in cavity preparation, it is important that the correct instrument be selected and the work which it is intended to do be completed before discarding it and using another. Multiplication of instruments and their haphazard use tends to slovenly work and waste of time. The accompanying tabulated instrument-selections and a number of illustrations depicting instrumentation are modifications of a valuable chart of Dr. Finn J. Bronner. These are based on a scientific study of instrument formulae, finger positions, fulcrums, measurement of teeth and arches and depth of cavities. The student should select the proper instruments as indicated for the performance of the various steps in the cavity on which he is operating and arrange them on the bracket table in the order of their use before beginning the operation. This will greatly assist in systematizing his work, increasing his efficiency and conserving his time as well as that of his instructor.

In the beginning, frequent reference to the instrument selection figures will be necessary. With experience and repetition, this will gradually become unnecessary through familiarity with the systematized technic. The majority of the hand instruments to be used have either three or four millimeter blade lengths and are of either 6, 12 or 23 centigrades angulation in the shank. These are the hand instruments most frequently used, those of other dimensions being indicated for special purposes. The great bulk of the operating is done with hand instruments, these more effectually producing the plane surfaces and line and point angles incident to the formation of the various mortise forms and also being better adapted to the cleavage and planing of most enamel walls. The round bur is suitable for opening into small pit and fissure cavities, but rarely for other purposes. It should not be used for removal of decay. The inverted cone bur is indicated for the undermining of underlying dentin, when it is necessary to extend enamel margins. It is also used for the preparation of convenience angles, although for this purpose hand instruments are often better adapted. The flat end fissure bur is valuable for squaring up and paralleling lateral walls in small cavities and also for flattening the floor of similar cavities. In small Class I cavities the fissure bur may also be used for preparing the enamel wall, these cavities being often too small to conveniently admit the use of planing instruments for this purpose

In experiments conducted with Doctor Finn J. Bronner to test the differences in smoothness of cavo-surface angles prepared by the plain fissure bur and the chisel, the author has found very little difference in results obtained by the use of the two types of cutting instruments. Enamel margins were prepared in a number of cavities of various classes, some with a number 57 fissure bur and others with S. S. W. hard bits number 13 and 14. These were placed under a high power lens and the results noted. Very slight if any differences were discernable. As a result of these experiments, it was concluded that long sweeps of enamel margins may better be planed with hand instruments, while with small cavities the plain fissure bur is indicated. Also, that practically no difference in smoothness of the enamel wall is apparent in the use of the two types of instruments—if any whatever, apparently in favor of the fissure bur. This is contrary to the belief which has existed in the minds of many dentists, who have insisted that smoother surfaces are obtained with the chisels. Doctor Black stressed the use of chisels for finishing enamel margins. However, there has been great improvement in the manufacture of burs since his day and more perfect and regularly aligned bur blades are being produced, which are capable of cutting more rapidly and evenly and leaving smoother surfaces. This would probably account for the rather uniform results obtained through the use of burs and chisels in the experiments above mentioned. Another important finding noted in these experiments was the apparent improvement in the cleanness and clear cut outline, under the microscope, of enamel margins thoroughly swabbed with pure alcohol following swabbing with dry cotton and the use of the chip-blower, over those cleansed with dry cotton and the air syringe or chip-blower alone. This would appear to indicate the advisability of the use of absolute alcohol as the final step in the performance of the toilet of the cavity.

USE OF INSTRUMENTS

In the use of hand-cutting instruments, the blade should be placed perpendicularly to the surface operated upon. This will greatly increase the cutting power of the blade and reduce the pain of operating. To accomplish this, it is necessary to select an instrument which possesses the correct angle in the shank to bring the blade in proper relationship with the wall operated on. This angle will vary, depending on the location of the cavity, the finger and operating position adopted and the resultant shaft elevation of the instrument used, viz., the relationship of the operator's hand to the cavity wall operated on. Figs. 376, 377 and 378.

Relation Number 1.—If the approach to the wall of the cavity is a direct one and the shaft of the instrument may be placed at a right angle to that wall while using a proper rest, an instrument with a straight shank or one with 6 centigrades angulation should be used. This result may be obtained in many instances, using the third finger of the right hand, or sometimes the second finger as the fulcrum or rest. Direct approach and straight or 6 centigrade instruments usually give the best results in operating.

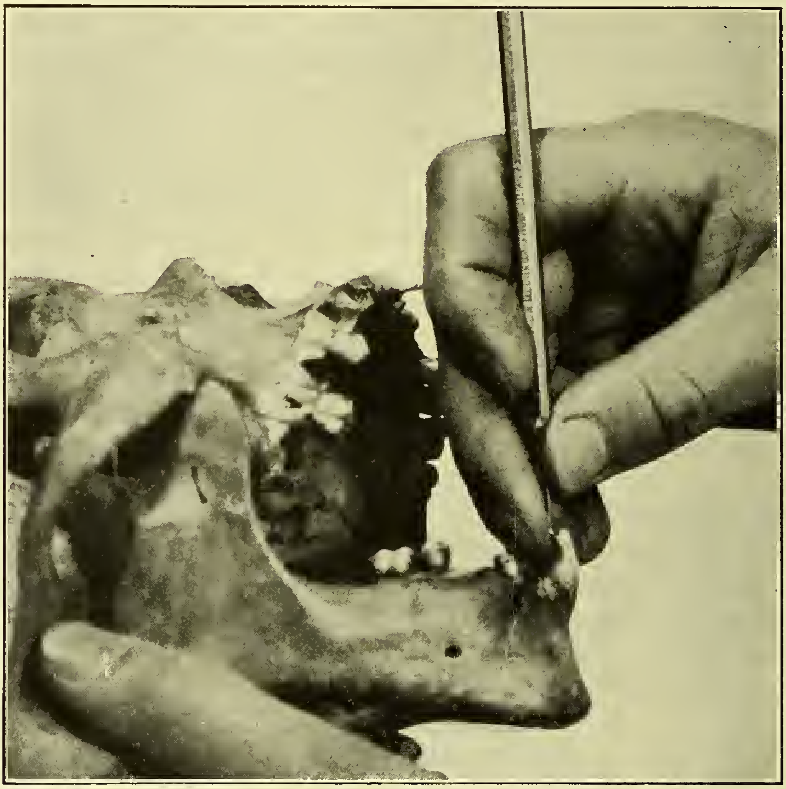


FIG. 376.—Modified pen grasp showing rest on second finger. An awkward grasp for patient and operator owing to faulty instrument selection. (Courtesy of Dr. Finn J. Bronner.)

Relation Number 2.—In case finger position number one is inadvisable or impossible and straight or 6 centigrade instruments are inadmissible, owing to the chair and operating position and location of the wall approached, the operating hand will often be moved back from the operating field the distance of one or two teeth, when it will be found that a 12, 18 or 15 centigrade instrument will accomplish the desired result. Fifteen centigrade instruments are now available for this purpose and are herewith recommended, 12 centigrade angula-

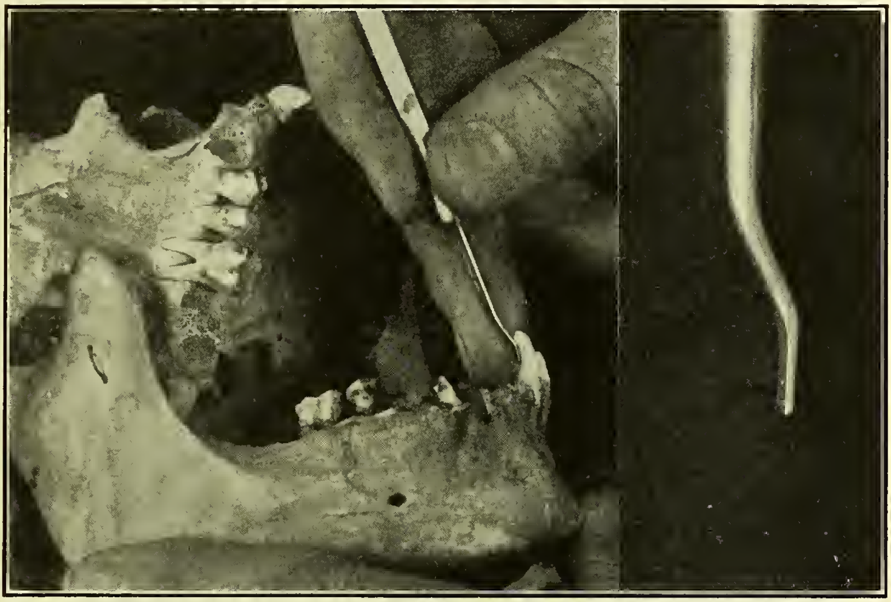


FIG. 377.—By selecting an instrument with correct angulation the blade is better and more easily brought in proper relation to the surface operated upon. (Courtesy of Dr. Finn J. Bronner.)

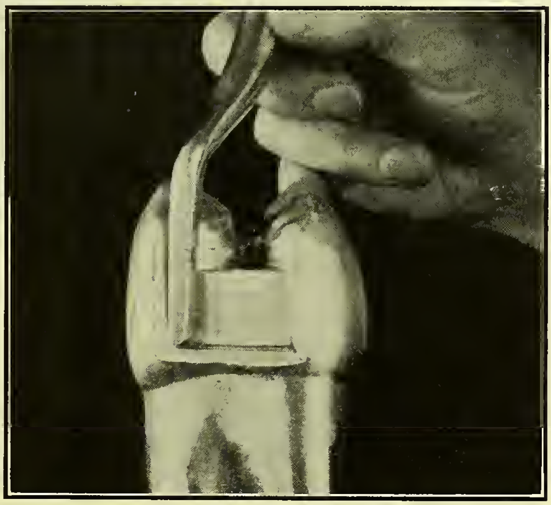


FIG. 378.—Instrument blade in correct relation to gingival wall of class II cavity. Incorrect instrument grasp and rest.

tion often being too small and 18 centigrade too large for ideal shaft elevation with this finger position.

Relation Number 3.—In other cases, particularly in gingival third cavities, the fulcrum or rest will be obtained still further away from the operating field or in a different relationship to it than in the two preceding positions; consequently, the selection of a 23 centigrade instrument will be indicated in order to bring its blade at approximately a right angle or 25 centigrades to the wall being prepared.

THE BRONNER ANGLE DETERMINATION APPARATUS

These facts are readily verified through measurements made with the angle determination machine (see Figs. 379 and 380), designed for this purpose by Doctor Finn J. Bronner. Doctor Bronner has made many measurements with reference to angulation and other factors concerned in scientific instrumentation. His measurements indicate that the average shaft elevation obtained for rests secured with the second finger is 13 millimeters, this being the average measurement of the width of the first and second fingers of various operators when using the pen grasp. With a rest on the third finger the elevation of the shaft is about 23 millimeters, this being the average distance from the surface rested upon through the fingers, when using the pen grasp in this manner. These measurements show that a relationship must exist between the elevation

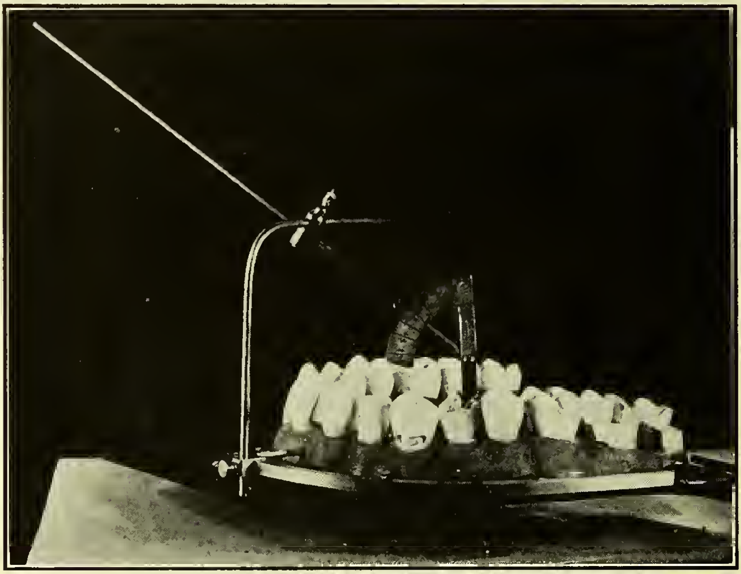


Fig. 379.—Dr. Bronner's angle determination apparatus.

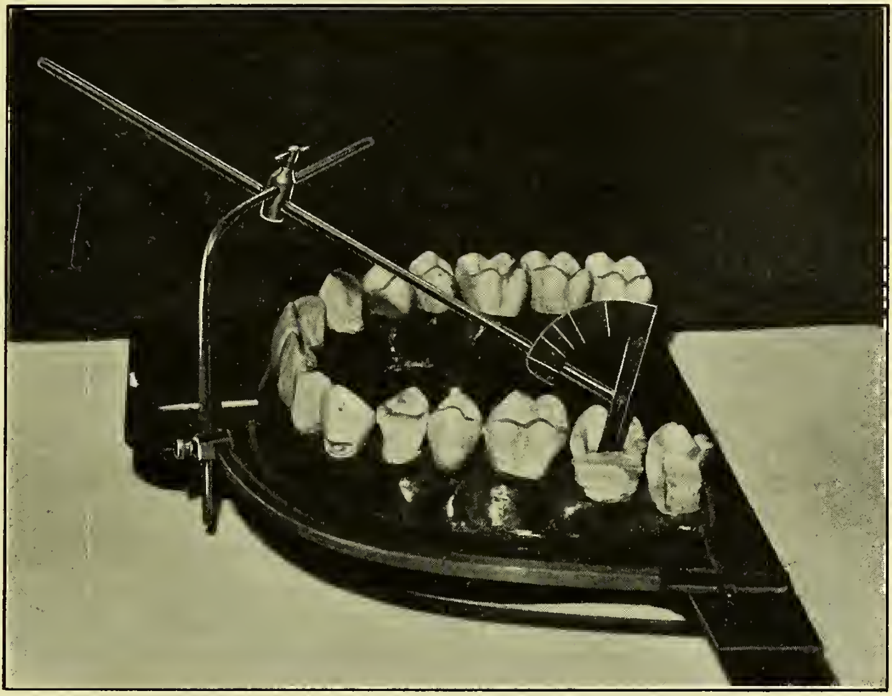


FIG. 380.—Dr. Bronner's angle determination apparatus.

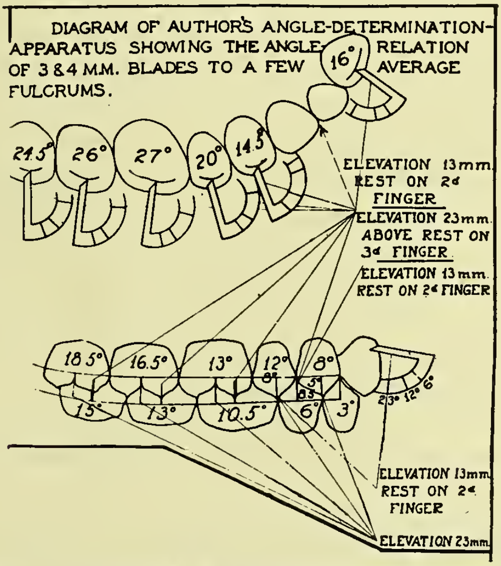


DIAGRAM OF AUTHOR'S ANGLE-DETERMINATION-APPARATUS SHOWING THE ANGLE-RELATION OF 3 & 4 M.M. BLADES TO A FEW AVERAGE FULCRUMS.
16°
24.5°
26°
27°
20°
14.5°
ELEVATION 13mm. REST ON 2d FINGER
ELEVATION 23mm. ABOVE REST ON 3d FINGER
ELEVATION 13 mm. REST ON 2d FINGER
18.5°
16.5°
13°
12°
8°
8°
5°
8.5°
15°
13°
10.5°
6°
3°
23°
12°
6°
ELEVATION 13mm REST ON 2d FINGER
ELEVATION 23mm

FIG. 381.—Diagram of Dr. Bronner showing important measurements in instrumentation.

of the shaft of the instrument as used with the pen grasp, the rest being obtained with the second or third finger, and the angulation of the instrument used. Thus, it is seen that the relationship of the blade of the instrument to the surface on which it is acting may often be regulated by a change of rest from the third to the second finger, or *vice versa*, as well as by moving the operating hand closer or farther away from the work. Doctor Bronner's measurements also indicate very clearly that ideal shaft elevation on bicuspids and molars is incompatible with a universal angle, this in spite of the possibility of a limited lateral adjustment of the shaft while operating through the corner of the mouth. The accompanying diagram (Fig. 381), used with the permission of Doctor Bronner, indicates the angle relation of three and four millimeter blades with a few average fulcrums obtained by use of the second or third finger in one or the other of the three finger positions previously mentioned. As emphasized by Doctor Bronner, variations in the shape of the curve of Spee will account for discrepancies between angle-registration on upper and lower teeth as obtained with his machine. Figs. 379 and 380.

PREPARATION OF CLASS I CAVITIES

These cavities occur in pits and fissures located on the occlusal surfaces of bicuspids and molars, the buccal surfaces of upper and lower molars and the lingual surfaces of upper incisors, more often on the laterals. Sometimes the lingual extremity of the disto-lingual groove on upper molars is also similarly affected. These pits and fissures are located at the points or lines of union of the enamel plates of the several lobes or centers from which the teeth are developed and are usually surrounded by faulty tooth structure, due to imperfect coalescence of the enamel plates. Their mode of treatment is similar, on whatever surface they may be located, the main differences in the instrumentation being due to differences in size of the cavity and the angle of approach. A description of the instrumentation for small and large occlusal cavities will be sufficient to enable the student to make the necessary modifications for other types of cavities of this class.

SMALL PIT AND FISSURE CAVITIES IN OCCLUSAL SURFACES

These are found in the floor of the central and distal fossae of upper molars, the central fossa on lower molars, the central groove of the upper first and second, and the lower second bicuspids, as well as in the mesial and distal pits of the lower first bicuspid.

Outline Form.—With a number ½ round bur enter the pit or fissure and enlarge the opening. Fig. 383. Now change to a number 55½ plain fissure bur and extend the margins to sound tooth structure. If the cavity is a fissure cavity, extent full length of the fissure and

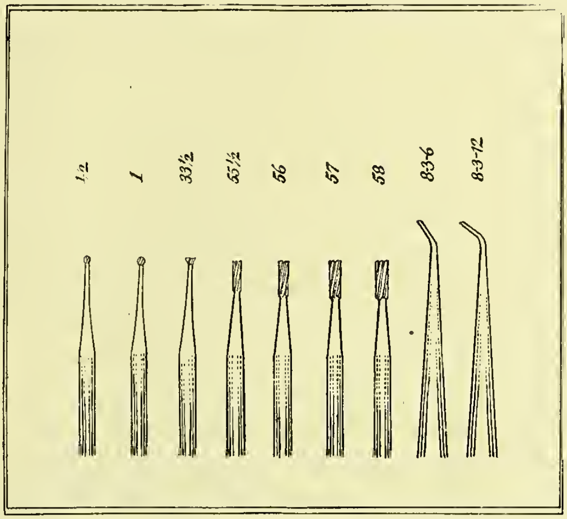


FIG. 382.—Instrument selection for small pit and fissure cavities in occlusal surfaces.*

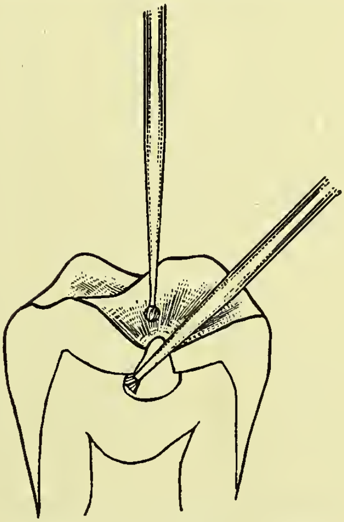


FIG. 383.—Opening a class I cavity with a round bur No. ½ or No. 1 and undermining the enamel with a 33½ inverted cone bur.

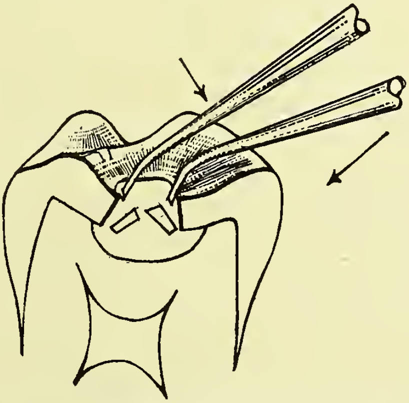


FIG. 384.—Cleaving the overhanging enamel with hoes 8-3-6 and 8-3-12.

* The drawings in this and the succeeding chapter showing instrumentation were drawn by Mr. Victor Lane from the instrument chart designed by Dr. Finn J. Bronner.

establish the mesial and distal margins in areas where a smooth finish may be given the filling. This procedure may require the use of a 56, 57 or 58 fissure bur, depending on the extension necessary and the amount of decay present. The mesial and distal triangular grooves at the termination of the central groove on the occlusal surface of bicuspids are often fissured, as is the central groove. If so, extend the cavity full length of these fissures, far enough to prevent future decay and to obtain good finishing margins for the filling. The buccal groove leading from the central pit on upper molars is also often fissured for a part of its length and demands extension of a cavity in the central fossa the full length of this fissure to an area where a good finishing margin may be obtained. The disto-lingual groove on the same teeth is often fissured its full length in which case the cavity is extended over on to the lingual surface to include the entire groove and lingual pit often seen at its termination. The mesial, distal, lingual, buccal and disto-buccal grooves leading from the central fossa on lower molars are often similarly fissured for a short distance, necessitating extension of cavities in the central fossa to include the fissures.

In cavities of slightly larger dimensions, a number 1 round bur may be used for entrance, when the enlargement and extension of margins may be accomplished with plain fissure burs number 56, 57 or even 58. In these larger cavities, it will sometimes be better first to undermine the underlying dentin with inverted cone bur number 33½ and then to cleave the enamel away with hoe excavators number 8-3-6 and 8-3-12. Fig. 384. Extension of the cavity to follow out fissured grooves is usually readily accomplished with the smaller fissure burs previously mentioned.

Resistance and Retention Form.—This is obtained by flattening the pupal wall (floor), paralleling the axial walls of the cavity, and uniting them to form well marked line angles. In these small cavities no dovetailing, no undercutting, is necessary, the parallel axial walls, flat seat and distinct line angles joining the pulpal with the axial walls being sufficient to retain the filling in position and to give it adequate resistance against stress. This is readily accomplished with the number 55½, 56, 57 or 58 fissure bur, depending on the size of the cavity. These cavities should not be cut deeply into the dentin. Fig. 385.

Convenience Form.—Convenience form is usually unnecessary in cavities so small. However, a small convenience point for starting gold may be placed in the most distal part of the cavity, if desired for beginners. It is made with a 33½ inverted cone bur.

Removal of Decay.—This has been already accomplished in this size of cavity during the performance of the previous steps. However, an inspection should now be made for any traces remaining, which, if found, may in the majority of instances be readily removed with the fissure bur without changing the shape of the flat pulpal wall previously formed.

Finishing the Enamel Margin.—The enamel wall should be made continuous and on the same plane with the dentin wall in small cavities of the class under consideration. No additional bevel is necessary, owing to the convergence toward the cavity of all surrounding rods. However, there is no great objection to bevelling the outer one-fourth or one-third the thickness of the enamel, if desired, to remove the sharpness of the cavo-surface angle of the cavity margin and to strengthen it against the stress incident to plugging cohesive gold. The smoothing and finishing of the enamel wall is most conveniently and efficiently accomplished with the fissure burs used in obtaining resistance and retention form. It has previously been mentioned that the plain fissure bur will give as smooth a finish to enamel margins of this type as will the chisel. This may readily be determined by preparing enamel margins on extracted teeth, some with plain fissure burs and others with chisels and comparing the results obtained with a magnifying glass or with the microscope. If bevelling of the cavo-surface angle is decided upon, it may be accomplished with the fissure bur, with hoes 8-3-6 or 8-3-12, ro with hard-bits number 13 and 14. Fig. 386. If used, a bevel of 3 centigrades, one-fourth to one-third the length of the enamel rods will be adequate.

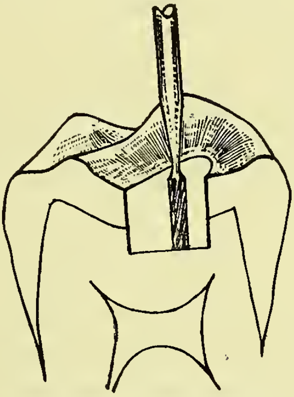


FIG. 385.—Obtaining outline and resistance form with a flat end fissure bur.

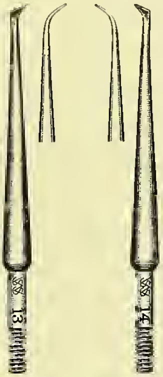


FIG. 386.—Hard bits.

Toilet of the Cavity.—This is performed in the manner described in the preceding chapter.

PROPHYLACTIC ODONTOTOMY

The theory and technic of this operation has been previously discussed in the chapters on Preventive Dentistry. In view of the fact that the majority of pits and fissures on the teeth may be considered as defective tooth structure, due to imperfect coalescence of the enamel at the junction of the lobes or centers during the developmental periods, and that they are always susceptible to caries, owing to food impactions and the impossibility of the brush reaching and removing the fermenting material located therein, they should be early diagnosed and either filled or immunized as a preventive measure.

Microscopic examination of these poorly calcified areas discloses the fact that they extend a variable distance into the enamel. In some instances, they penetrate through to the dentin, while in others they do not, there being a layer of enamel between them and the dentin. In many instances they are so minute that a fine pointed explorer or the finest tooth brush bristle will not enter them. The photomicrographs of Doctor C. F. Bödecker shown in Chapter V readily reveal this. Although the explorer or tooth brush bristle will not enter, the oral secretions, food and germs easily do so, with the result that their presence may be considered a menace. Doctor Bödecker claims that in a fissure 0.26 mm. wide, 8,400,000,000 bacteria may remain undisturbed, while one 0.07 mm. × 1 mm. × 0.5 mm. in dimension may accommodate 2,800,000,000 micro-organisms. Dental caries often begins in defective pits and fissures soon after eruption if the patient is at all susceptible. It is important for the dentist to know whether pits and fissures completely penetrate the enamel, in order that he may determine whether they should be opened, a small cavity be prepared and filled or whether they should be immunized. In the great majority of cases, the filling operation is indicated, because on preliminary opening of the cavity with a number ½ round bur, it will be found to be either decayed or to penetrate to the dentin.

The technic of cavity preparation in these cases is the same as that just described for small pit and fissure cavities. In view of the desirability of detecting them soon after eruption of the teeth, if diagnosis is made early, usually a very small cavity may be prepared by opening with a number ½ round bur, preparing the resistance and retention form and the enamel wall with a number 55½ square end fissure bur, when it is ready for filling. If detected later and caries is present, it may be necessary to extend the walls more, when a number 56 or 57 fissure bur will be indicated for this purpose. In other cases, especially later in life, the presence of caries may necessitate greater extension of margins and deeper cavities. In a few cases in children, where the preliminary opening of the pit or fissure reveals no decay and absence of penetration through the enamel, the immunizing operation may be performed. For a description of this latter operation see index.

LARGE OCCLUSAL CAVITIES

These may involve either the central or distal fossa of upper molars or both, or in some cases caries may be so extensive that the oblique ridge has been destroyed and a large part of the occlusal surface is involved. In other cases, although both fossae are decayed, the case still presents as two separate cavities, although with deep involvement of the oblique ridge, necessitating its removal and uniting the two cavities. Often penetration of decay is marked and wide-spread, requiring bold extension of the outline form and deep cutting for its removal.

The operator should be thoroughly conversant with the external and internal anatomy of the tooth on which he is operating, including the thickness of the enamel and dentin, the size and location of the pulp chamber, the position of the cornuae and recessional lines, and the bearing of age on this latter condition. The horns of the pulp lie under the cusps and are much closer to the surface in young teeth than in older persons, there being a gradual recession and diminution in size of the entire pulp with age. They are longer in teeth with long sharp cusps than in those with short obtuse cusps. As a result, they will be more readily exposed in younger patients and in teeth with long cusps than in the opposite types. When the teeth are first formed the pulp cornuae are very near the surface. As the dentin is deposited, the cornuae recede and the route of their recession is known as the recessional lines of the pulp cornuae. Often a minute extension of the pulp horn is left in a recessional line until or past middle age, with the result that careless cutting during the preparation of a cavity may produce an exposure, which may necessitate removal of the entire pulp. In bicuspids and molars the recessional lines extend from the cornuae toward the point of the cusps as seen in Fig. 388.

The mesio-buccal horn in both upper and lower molars and the mesio-lingual in lowers are usually the longest and more likely to be exposed in operating. In all of the molar teeth, the mesial pulpal horns are longer than the distal, consequently, there is greater danger of exposing them or the recessional lines in mesial than in distal cavities.

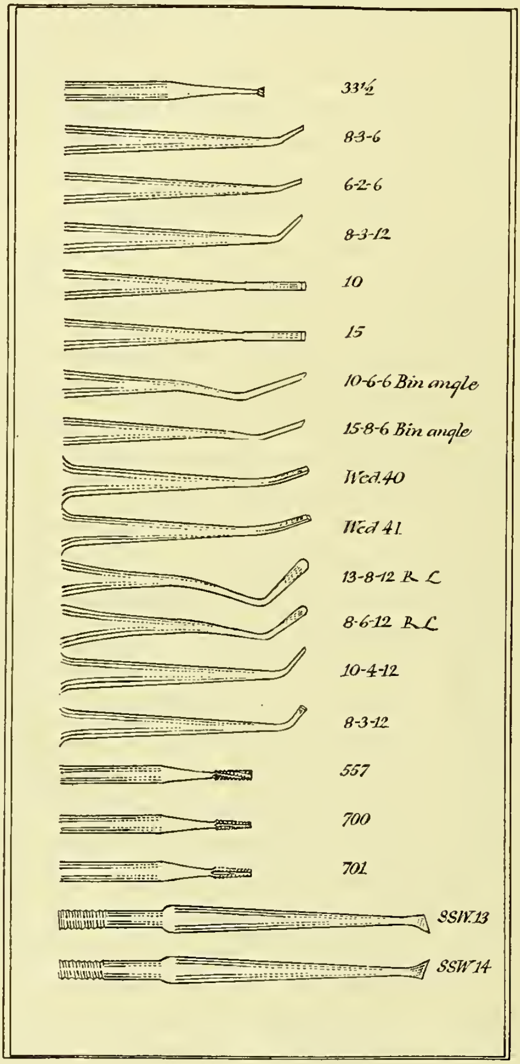


FIG. 387.—Instrument selection for large occlusal cavities.

According to measurements of many teeth made by Doctor Finn J. Bronner, the enamel on occlusal surfaces of bicuspids and molars ranges in thickness from about 2.3 millimeters over the cusps of bicuspids to 2.6 millimeters over the cusps of molars, being thickest over the cusps and thinnest in the location of pits and fissures. The average thickness of dentin in the same localities is from 2 to 3 millimeters. Over the horns of the pulp this will vary greatly, depending on the length of the horns. Doctor Bronner's measurements for the total thickness of enamel and dentin on occlusal surfaces of molars are; at the center of the surface 3.5 to 6 millimeters, over the cornuae 3.2 to 5 millimeters, the average thickness over the entire surface of many teeth measured being 4.3 millimeters. He found the average distance between the pulp horns in molars to be 3.1 millimeters.

These measurements afford very valuable information, since they have a definite bearing on the depth of cavity walls in their relationship to the pulp horns, and the amount of lateral extension admissible in these localities. An examination of Fig. 388 will clearly show the danger of exposing the cornuae from recklessly extending the walls of these cavities both laterally and pulpally.

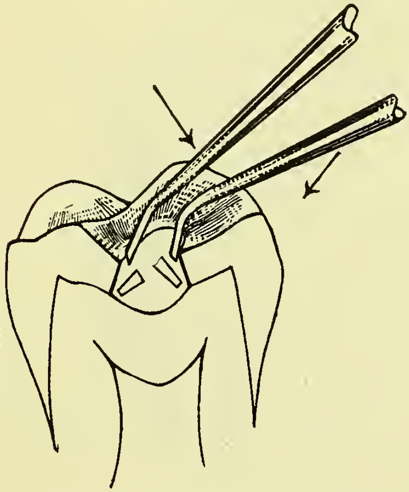


Fig. 388.—Cleaving the enamel away in a medium size cavity with hoes 8-3-6 and 8-3-12.

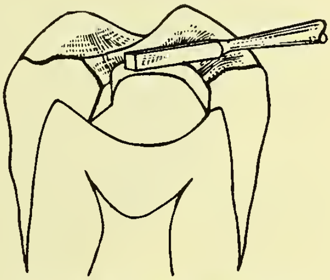


Fig. 389.—Establishing outline form with a straight chisel No. 15.

Outline Form.—The cavity is open and fully exposed to view. Often an ashy discoloration shows through the enamel bounding the margins, indicating partial disintegration of the enamel.

Begin the operation by chipping away the overhanging and unsupported enamel. The instruments indicated will depend on the size and location of the cavity. For medium sized cavities hoes 8-3-6 and 8-3-12 will be indicated. Fig. 388. For those of larger size, straight chisels 10 or 15, bin-angle chisels 10-6-6 or 15-8-6 or Wedelstaedt's chisels 40 and 41 will be better. Fig. 389. The hoes or chisels may be used with hand pressure or the mallet. In many instances hand pressure will be preferred. If the mallet is used, the chisel should be held in the left hand, using the third finger as a rest. It should be placed on the edge of the enamel and held securely to prevent slipping into the cavity and producing pain when the blow is delivered. A single, quick, sharp stroke of the mallet will direct the chips into the cavity. Continue the chipping around the margins of the cavity until sound dentin is found supporting the enamel. Then if further extension is necessary, undermine the underlying dentin with inverted cone bur number 33½, when the chipping of the enamel may be continued until the extension is satisfactory. Figs. 390 and 391. With an increase in the size of the cavity it will be found that the lines of cleavage of the enamel will radiate outward more and more as the cusps are approached.

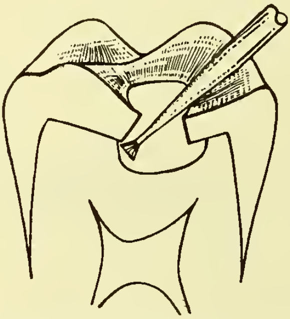


Fig 390.—Undermining the dentin before removing overlying enamel walls.

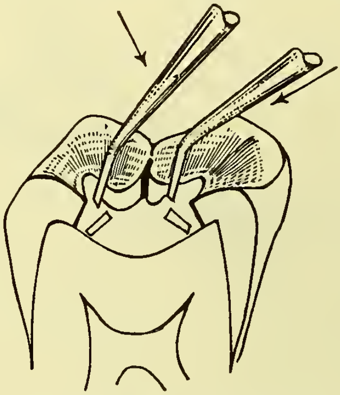


Fig. 391.—Chipping the enamel in large class 1 cavity after removing the underlying dentin with a 33½ inverted cone bur.

The instruments used for this purpose should be of razor-like sharpness. In cleaving enamel the chisel, however sharp, does not enter the cementing substance between the rods. The rods are, according to Frederick B. Noyes[1] 3.4 to 4.5 microns in thickness, while the cementing substance is much thinner. Hopewell-Smith[2] gives the diameter of enamel rods as 5 microns, while Kolliker[3] says they are from 5.1 microns to 6.4 microns in breadth. Fig. 392. Charles F. Bödecker claims they average 4 microns at their inner ends and 7 microns at their outer extremities, this being necessary to fill in the additional bulk of enamel on the surface. This is disputed by Noyes and other histologists, some of whom claim the presence of numerous short rods in the outer enamel layers, lying in between the full length rods, which fill in the spaces and thus make up for the greater width of the enamel on the periphery. Others claim that the difference is compensated for by increased width of the inter-rod substance on the surface. Hopewell-Smith[4] states that the cementing substance varies in thickness and averages about 1 micron in width. Thus are the histologists again in dispute on a very important matter.

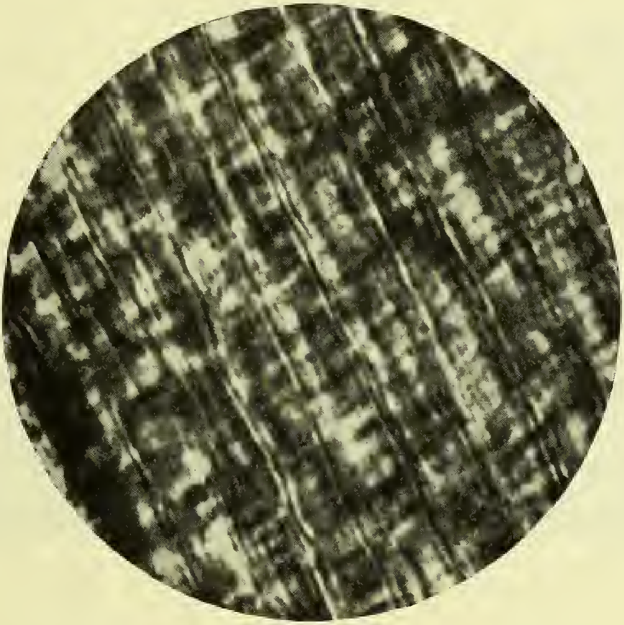


FIG. 392.—Structure of enamel. (Courtesy of Dr. J. Hopewell-Smith and "The Dental Cosmos.")

As stated, the edge of the chisel, in cleaving enamel, does not insert itself between the rods. Hopewell-Smith[5] has calculated that the sharpest edge attainable would be of the thickness of about sixteen rods. However, a very sharp chisel engages with the surface of the enamel and fractures the tissue in the lines of cleavage or direction of travel of the rods. Many rods are crushed and crumbled during the act of enamel cleavage, the duller the instrument, the greater the force required and the greater number of crushed rods. This fact still further emphasizes the importance of frequent sharpening of all enamel-cutting instruments. Fig. 393.

The direction of the enamel rods in various localities has been described in the previous chapter. Both Noyes[6] and Bödecker[7] state that on the axial surfaces of the teeth, they usually follow a straight course, particularly in the gingival third, while on occlusal and incisal surfaces, although their outer ends are straight, the middle sections and inner ends are gnarled. The accompanying drawing of Doctor Bödecker (Fig. 394) shows that on the occlusal two-thirds of the crowns of bicuspids and molars the rods are gathered together into bundles, interlace and follow a spiral course. Thus it may be readily understood that with straight enamel rods, as found on axial surfaces, they may be readily split with the chisel straight through to the dentin. On occlusal surfaces, however, the outer ends of the rods, being straight will split only part way, while they will likely break across where they interlace and follow a wavy course in the deeper layers of the enamel. Consequently, the necessity for careful planing and finishing enamel walls on the completion of the cavity preparation, to remove the ends of crushed rods and to smooth the ends of cut rods, is further emphasized.

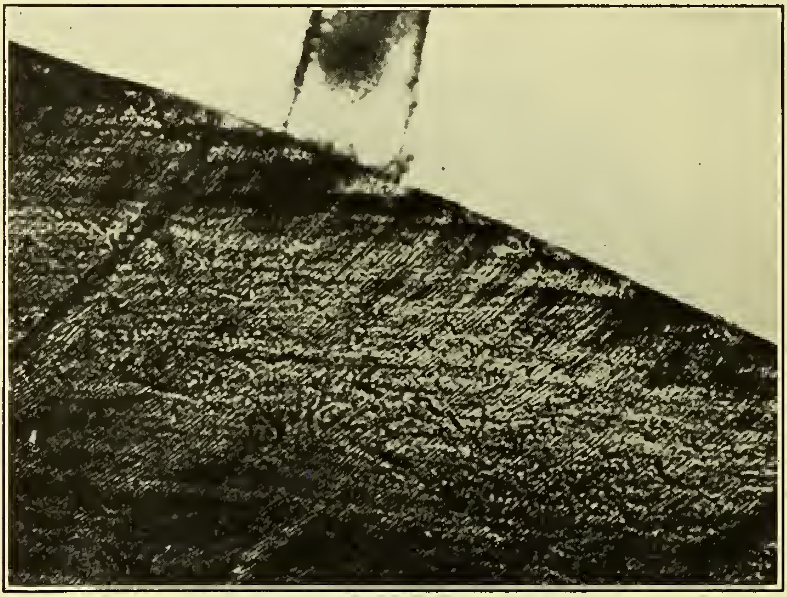


FIG. 393.—The end of a toothbrush bristle applied to the free surface of human enamel. (Magnified 50.) (Courtesy of Dr. J. Hopewell-Smith and "The Dental Cosmos.")

On the completion of the enamel cleavage, any grooves entering the cavity which are fissured, or which will interfere with a smooth cavity margin, should be opened as far as necessary, to prevent future decay and to give a good finishing margin for the filling. For this purpose, plain fissure burs number 56, 57, 58 or cross cut fissure burs 557,700 or 701 are indicated, depending on the size of the fissure and groove. Fig. 395. After opening, if additional enlargement is advisable, it may be done by first undermining the underlying dentin with the 33½ inverted cone bur and then removing the surrounding enamel with the fissure bur or the hand cutting instruments previously mentioned. It is not necessary to cut these grooves as deeply as is the main cavity unless decayed to that depth. Cutting into the dentin just enough to secure sufficient depth for retention is usually all that is admissible. Unnecessarily deep cutting here will sacrifice too much tooth structure, often weaken the attachment of the cuspal elements of the tooth and endanger the recessional lines of the pulp. Fig. 396.

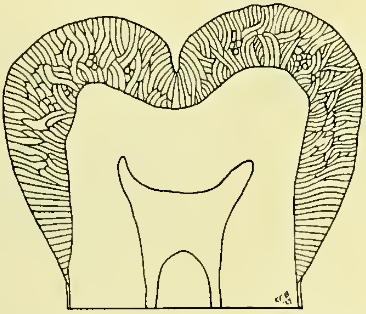


FIG. 394.—Structure of enamel on bicuspids and molars. The rods appear parallel in the gingival third, while on the occlusal third and occlusal surface their outer ends are parallel but their middle section and inner ends are gnarled. (Courtesy of Dr. C. F. Bödecker and "Dental Items of Interest.")

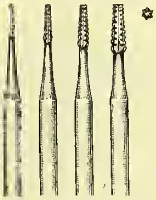


FIG. 395. Tapered fissure burs, No. 700, 701, 702 and 703. Cross cut.

Removal of Decay.—The decay will have penetrated deeply in many cases of large occlusal cavities and, after establishing the outline form, the question will often arise as to the depth of penetration and as to whether it has involved the pulp. For this reason in many instances the removal of carious dentin should be placed as the second step in cavity preparation and be given consideration at this time. If pulp exposure is suspected, examination of the carious matter should be conducted very carefully to avoid pain. The walls of the cavity should first have been so extended that the margins of the carious area may be seen and readily approached. The effort should now be made to carefully and gently lift the softened dentin out of the cavity *en masse* with one or two strokes of a spoon excavator. The spoons indicated for this purpose are 13-8-12, 10-6-12 or 8-6-12, right and left, depending on the size of the cavity.

Fig. 397. The sharpened edge of the instrument should be carefully introduced under the most accessible margin of the carious area and gently but quickly forced under it, avoiding as far as possible pressure in the direction of the pulp. An effort should be made to lift out the entire mass with one stroke, following as nearly as possible the hard underlying dentin. Failing in this, a second or third sweep of the instrument from a different direction should completely remove it. Following this, any remaining softened matter should be gently scraped out with the same instruments and the cavity cleansed. If the pulp has not been exposed, the case is ready for the performance of the next step; if exposed, it will be ready for treatment and removal. In very large cavities of this type, especially if very painful, it will occasionally be advisable to make no attempt to complete the outline form until most of the decay is removed. In such cases, the outline form should now be perfected and all necessary connecting grooves cut out. In other cases, these details will previously have been attended to.

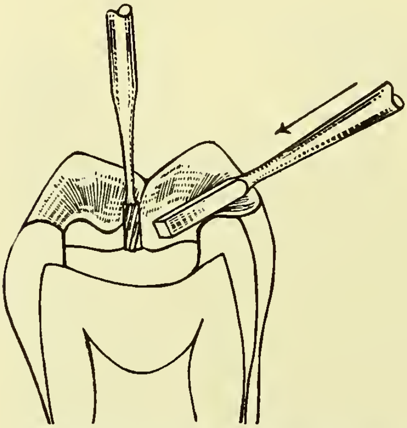


Fig. 396.—Chiseling the enamel with a straight chisel No. 15 and entering connecting grooves with a fissure bur.

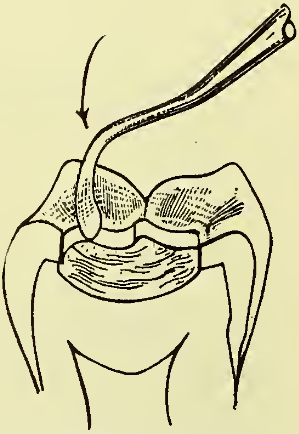


Fig. 397.—Removal of decay with spoon excavator No. 13-8-12.

Resistance and Retention Form.—After the decay is removed the cavity will usually present a generally rounded interior with concave axial and pulpal walls. If the pulp will not be endangered, the axial walls should now be squared up and paralleled and the pulpal wall made flat and joining the axial walls at the 25 centigrade angle to obtain the box or mortise form (simple mortise on one surface). Distinct and definite line angles should mark the junction of the pulpal and axial walls. This will afford the necessary resistance and retention form, no undercutting or dovetailing of the lateral walls being necessary. Figs. 398 and 399. This procedure is best accomplished with hoes 10-4-12 and 8-3-6 and hatchet 8-3-12, cutting and scraping with the edge and sides of the blades. The sides of the blades of all hoes are valuable for cutting purposes if kept sharp. With lower molars a convenient rest may often be obtained for this purpose over the median line of the upper front teeth or sometimes on the cuspid of the opposite side. Fig. 400. In lower second and third molars hoe 8-3-23 also will occasionally be of assistance. The bur is a much less effective instrument for preparing resistance and retention form in these types of cavities. However, fissure bur 57 or 58 may occasionally be resorted to for assistance in preparing some particular part which is difficult to reach with the hoe and hatchets, but it should not supplant them and should be discarded as soon as its work is complete in touching up a difficult wall. If used at all, care should be observed not to endanger the recessional lines of the pulp and to avoid heat through friction. As previously stated, it will be valuable for squaring out any connecting grooves and giving them the box form necessary for resistance or retention. In these cases, the extremity of the groove should not be allowed to gradually disappear or round over on to the surface but should be definitely squared out and made retentive in form. Particularly is this the case in following out the disto-lingual groove to its extremity on upper molars and the buccal grooves on lower molars. In preparing these latter grooves, it is well to

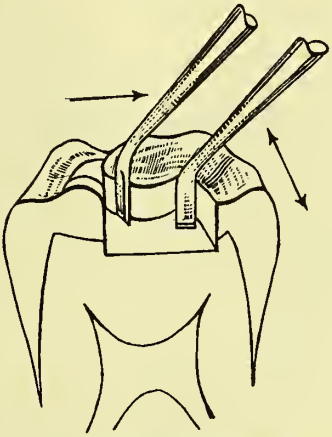


FIG. 398.—Cutting resistance and retention form with hoe 10-4-12 and hatchet 8-13-12, scraping with edges and sides of blades.

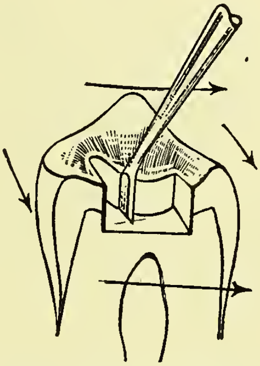


FIG. 399.—Cutting resistance and retention form in a first bicuspid with hoe 8-3-6.

remember that they pass over or near to the extremities of the recessional pulp lines with consequent danger of exposing them. For this reason, they should be left shallow and should usually pass over on to the buccal or lingual surface in the form of a step and be acutely flattened at their extremity. This form will avoid the recessional lines and give the necessary resistance and retention. (Fig. 336.)

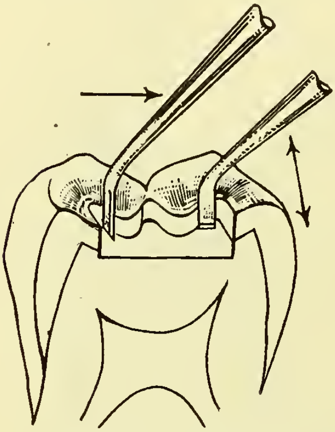


Fig. 400.—A shallower cavity than that shown in 398, being prepared with the same instruments.

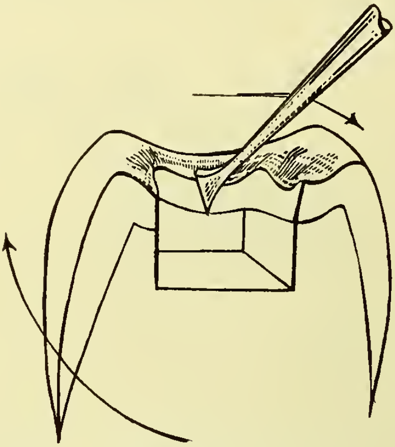


Fig. 401.—Finishing the enamel wall with a hard bit.

In many large cavities, the extension of the decay will sometimes approach closely to the mesial or distal marginal ridges. In the exaggerated cases, it will sometimes be necessary to remove the affected marginal ridge, extend over on to the proximal surface and prepare a Class II cavity. In many instances, however, if decay is absent on the proximal surface, this may be avoided. Under these circumstances, if the mesial and distal walls of the cavity were paralleled, the marginal ridge closely approached would be greatly weakened. To avoid this, the dentin wall, instead of being made perpendicular in the axial plane, should be made to slope toward the marginal ridge, thus leaving in place a larger body of supporting dentin below, to support the marginal ridge. This procedure may be followed with one or both of these walls if sufficient dentin is left on the buccal and lingual walls to allow for paralleling them, this form often affording adequate retention for the filling, without undercutting.

In cases of deep cavities with extensive lateral decay, the flattening of the pulpal floor would greatly endanger the pulpal horns. In order to avoid this and at the same time gain sufficient resistance form, the center of the pulpal wall may be left untouched and a ledge of dentin be cut at a higher level completely or partially surrounding the axial walls and above the floor of the cavity. It will not be necessary to cut this ledge completely around the cavity if there is great risk of exposing a horn. However, sufficient ledges should be obtained to afford ample resistance form. This ledge should be cut with the same instruments previously recommended for flattening the pulpal wall and obtaining resistance and retention form. The central rounded portion is filled in and levelled up to the ledges with cement before insertion of the filling.

Convenience Form.—For gold fillings, it will occasionally be necessary to slightly extend or slope the mesial, or buccal walls of the cavity to gain additional access to enable the operator to plug the gold with direct mallet force against all walls. This is not necessary for amalgam work. This procedure is more particularly applicable to upper second or third molars, where the mesial wall may be sloped, or to lower molars, which may require sloping of the buccal wall. The placing of convenience pits in the distal part of the cavity may be resorted to if desired. They should be cut with inverted cone bur 33½ into the axial walls farthest distal, and not into the pulpal wall.

Finishing the Enamel Wall.—The enamel walls should now be planed to form and made smooth. In medium sized cavities, they may be made parallel with the dentin walls, but if the cavity is larger, the enamel wall should incline more and more outward as the cusps are approached, following the lines of cleavage of the rods. Usually an outward inclination from the axial plane of 3 centigrades, involving the entire thickness of the enamel will be sufficient. A supplementary bevel of the outer ⅓ of the enamel wall may be made if desired, but in large occlusal cavities this is usually not necessary. Hard bits 13 and 14 are indicated for finishing and beveling the enamel wall. Fig. 401. They should be used with a pull cut, scraping, not occluso-pulpally, but all around the cavity in the direction of the marginal outline. If desired, straight or bin-angle chisels, 1 or 1.5 mm. blade may be substituted. The enamel wall of any connecting grooves which have been opened may be prepared with the same instruments or often just as well, or more efficiently with fissure burs 57 or 58. The same may be said for some medium sized cavities of Class I, where the sweep of the marginal outline is not long.

Toilet of the Cavity.—This should be carefully completed, following the procedures for this step outlined in the previous chapter.

PIT AND FISSURE CAVITIES IN OTHER LOCALITIES

These occur in pits on the buccal surfaces of upper and lower molars, on the lingual surfaces of upper incisors (more often the lateral incisors), in the termination of the lingual groove in upper molars and more rarely in the mesio-lingual groove of upper first molars, when there is a fifth cusp.

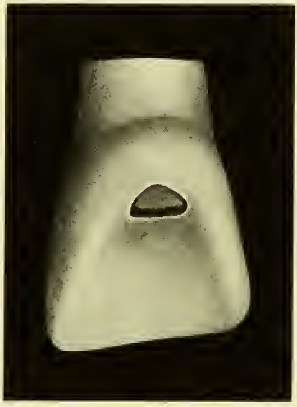


Fig. 402.—Pit cavity (Class I) on the lingual surface of an upper incisor.

The instrumentation for their preparation is similar to that for Class I cavities on occlusal surfaces and it is not necessary to enter into a minute discussion of it The same types of instruments are used as for the preceding cases and the same fundamental principles are observed. In small buccal pits, the cavity may be opened with a ½ round bur and the preparation usually completed with fissure bur 56, 57 or 58. If the buccal groove is involved, the cavity may occasionally be carried along the groove to a good finishing margin at the crest of the buccal marginal ridge on the occlusal surface and be finished with the same instruments. However, in the majority of cases, the extension will have to be carried over into the central pit of the occlusal surface, including more or less of the occlusal grooves. In these cases, decay is also frequently found on the occlusal surface, so that this treatment would be necessarily indicated, thus uniting the cavities. Owing to the tendency to early and deep penetration of decay in cavities in lingual pits in the upper anterior teeth, they should be sought early and filled. Fig. 402. They may be opened with a ½ round bur followed by a 56 or 57 fissure bur, but care should be observed not to penetrate deeply and endanger the pulp. The rest of the preparation should be made with hand instruments, such as hoes and hatchets 6-2-6, 8-3-6 and 6-2-12, 8-3-12, for this reason. The pulp is usually very close to the surface here, particularly in young teeth. The average thickness of enamel and dentin in this locality is 2.5 millimeters on centrals, 2.1 millimeters on laterals and 2.9 millimeters on cuspids (Bronner). Owing to the marked inclination incisally of the enamel rods on the incisal margin, the enamel wall here should be given proper inclination incisally to give it the necessary strength.

Bibliography

1. Noyes, Fred. B.: "Am. Text-book of Operative Dentistry," 6th ed., p. 176.
2. Hopewell-Smith, Arthur: "Normal and Pathological Histology of the Mouth," vol. I, p. 25.
3. Kolliker: "A Manual of Human Microscopic Anatomy," 1860.
4. Hopewell-Smith, Arthur: "Normal and Pathological Histology," vol. I, p. 32.
5. Hopewell-Smith, Arthur: Concerning human enamel, Dental Cosmos, vol. LXVIII, July 1926, p. 7.
6. Noyes, Fred. B.: "Am. Text-book of Operative Dentistry," 6th ed., p. 179.
7. Bödecker, Chas. F.: Differences in penetration of caries, etc., Dental Items of Interest Jan. 1928.

Hyatt, Thaddeus P.: Prophylactic odontotomy, Dental Cosmos, Feb. 1924.

Hyatt, Thaddeus P.: Questionnaire on occlusal fissures and their treatment, Dental, Cosmos, Nov. 1926.

Hyatt, Thaddeus P.: Occlusal fissures, Bulletin, Metropolitan Life Ins. Co., 1924.

CHAPTER XIII

A STANDARDIZED SYSTEM OF INSTRUMENTATION FOR CAVITY PREPARATION (*Continued*)

INSTRUMENTATION FOR CLASS II, CLASS III, CLASS IV AND CLASS V CAVITIES

PREPARATION OF CLASS II CAVITIES

Under this heading is presented the treatment for caries beginning on the mesial and distal surfaces of bicuspids and molars. In these cases, the general rule is to extend the cavity over the mesial or distal marginal ridge on to the occlusal surface in the form of a step, in order to obtain a better seat for the filling and also to secure the necessary access for its proper introduction, contour and restoration of its contact point. There are very few exceptions to this rule and the cases demanding these exceptions are very rare. They are (1) where the proximating tooth is absent and not to be replaced, the decay being on the *mesial* surface with the marginal ridge unaffected; (2) the presence near the gingiva of a proximal surface decay (so-called senile decay) in the aged, when it is desired to avoid extensive cutting; (3) in cases requiring temporary operations in convalescence, pregnancy, youth, old age and similar conditions. Under these exceptions, if the marginal ridge is unaffected, the case may be allowed to remain on the proximal surface and a simple cavity be prepared.

The same danger exists in Class II cavities with reference to cutting into the recessional pulpal lines and exposure of the pulpal horns as mentioned in connection with Class I cavities. In fact, these dangers were greatly magnified in Class II cavities as they have been prepared in the past. The wide bucco-lingual extensions of the *parallel* buccal and lingual walls of the proximal part of the cavity, with the consequent necessity for destruction of cusp structure at the location of the marginal ridge, and also the necessity for rather wide bucco-lingual extensions of the step, in order to secure the necessary retention form, resulted in great loss of tooth structure. Most of the criticism in the past against the supposed extensive cutting of tooth structure involved in modern cavity preparation has been directed against the preparation of proximo-occlusal cavities as at present taught and practiced in many dental schools. The opponents of this practice have repeatedly called attention to the destruction of tooth structure involved in the extension of the buccal and lingual margins of the proximal part of the cavity, thus necessitating loss of much dentin on the buccal and lingual walls in order to parallel them; to the weakening of the buccal and lingual cuspal lobes and the marginal ridges, which assist in binding these lobes together, resulting from the same practice; and also to the resultant necessity for wide bucco-lingual cutting of the step portion in order to gain sufficient retention for the material placed in the proximal part of the cavity.

A NEW CLASS II CAVITY

The previously accepted preparation of this type of cavity is presented and fully described in Chapter XI. *Those teachers who desire to continue with the old form are thus conveniently enabled to do so.* The Class II cavity herewith presented is based on scientific principles, has been a gradual evolution from the old form and has now stood the test of time and experience.

Chief Characteristics.—For convenience, the old and new cavities are presented side by side in Figs. 403 and 404. By referring to these illustrations, it will be observed that the chief differences between the two forms are as follows:

1. In the new form, the buccal and lingual margins converge gingivo-occlusally; in the old form they are parallel.

2. In the new form, that portion of the buccal and lingual dentinal walls in proximity to the axial wall and lying near the region of the pulp horns and recessional lines converges gingivo-occlusally even more than the buccal and lingual margins; in the old form the buccal and lingual walls are parallel.

3. In the new form, this portion of the converging buccal and lingual walls is made 25 centigrades (right angles) to the axial wall and is wider at the gingival portion than at the top of the step—in fact it disappears here—while the remaining areas of the buccal and lingual walls flare out to the converging buccal and lingual margins; in the old form this feature is entirely absent. Fig. 405.

4. In the new form this innovation is really a dovetail mortise presenting two buccal and two lingual axial line angles which converge and disappear at the top of the step, the two buccal line angles converging together, the two lingual line angles doing the same, and all

four converging toward the central axis of the tooth; in the old form these features are omitted. Fig. 406.

5. In the new form, as a result of this arrangement, much of the enamel and dentin of the marginal ridge and the cusps is preserved, thus strengthening the anatomical and architectural features, while at the same time adequate resistance and retention are gained and the margins are still placed in immune areas; in the old form the marginal ridge and cusps are frequently weakened as a result of the loss of underlying dentin, and much more of the enamel is removed, without comparatively increasing the relative immunity of the marginal outline.

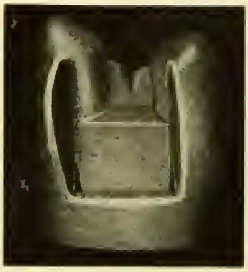


Fig. 403.—Proximo-occlusal cavity (old form).

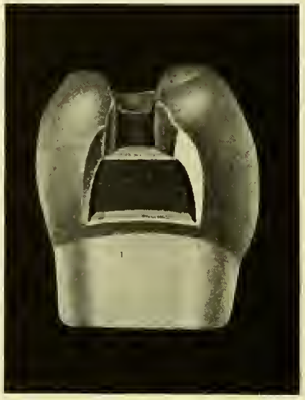


Fig. 404.—Proximo-occlusal cavity (new form).

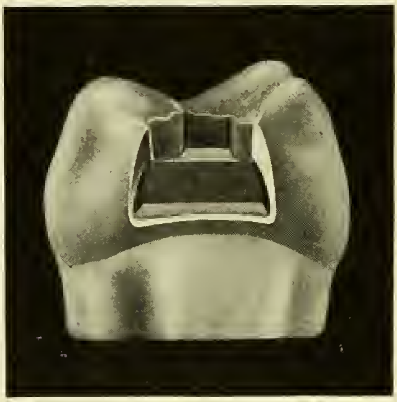


Fig. 405.—Class II cavity in a molar. New form.

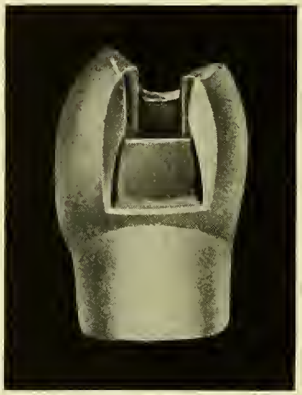


Fig. 406.—Class II cavity in a bicuspid. New form.

6. In the new form the preparation of the proximal dovetail mortise, the converging of the axial line angles and buccal and lingual margins, and

the outward flare of the remaining portion of the dentinal walls, greatly minimizes the danger of exposure of the cornuae and recessional lines of the pulp; in the old form these dangers are always present.

7. In the new form the resistance is increased by the greater area of the converging axial line angles and buccal and lingual walls, and the retention is well provided for by the dovetail mortise form of that part of the buccal and lingual walls lying next to the axial wall. In the old form the dovetail feature is absent, thus requiring marked accentuation of the bucco-gingivo-axial and linguo-gingivo-axial point angles, and the area of frictional contact for the filling material is less, due to the square box form and lack of converging line angles and walls, It may be readily understood by referring to the illustrations that converging line angles running from the gingival wall to the top of the step will be longer than parallel line angles running perpendicularly.

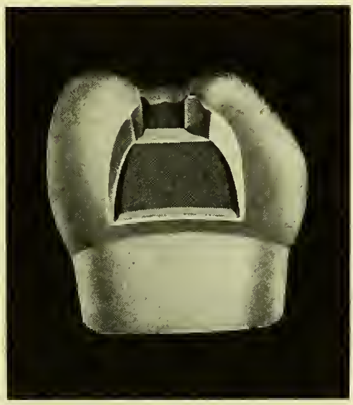


Fig. 407.—Class II cavity in a molar. New form.

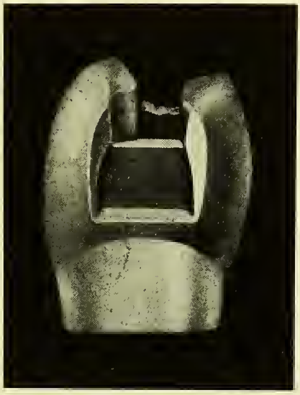


Fig. 408.—Class II cavity in a bicuspid. New form.

8. In the new form the increased resistance and retention form in the proximal portion greatly reduces the necessity for extensive bucco-lingual cutting in the step portion of the cavity for this purpose, thus frequently saving additional tooth structure on the occlusal surface. Fig. 408.

Advantages.—Thus it is seen that the principal advantages of the cavity form here advocated are (1) preservation of tooth structure and strength without loss of resistance and retention form; (2) diminution of the danger of cutting into the recessional lines and pulp horns; (3) placing of the cavity margins in relatively immune areas without extensive cutting; (4) increasing the resistance and retention form in the proximal part of the cavity with a minimum of loss of tooth structure; (5) diminution of the encroachment on and weakening of cusp structure; and (6) lessening of the necessity for deep pulpal walls and wide bucco-lingual extension in the step on occlusal surfaces. Reference to Fig. 409 will reveal the usual anatomical form, bucco-lingually of the bicuspids and molars and show the converging proximal outline suitable for these teeth. The location of the contact point is seen. The average measurement of the contact point gingivo-occlusally and bucco-lingually on molars is 1.5 millimeters to 2 millimeters, it being usually wider bucco-lingually. From this point the proximal surface rounds out into the buccal and lingual embrasures and occlusally toward the mesial and distal marginal ridges. In this locality, the areas between the contact point, the buccal and lingual surfaces and the crest of the marginal ridge are out of contact with the proximating tooth and are relatively immune to dental caries. As much of these areas should be preserved in laying down cavity margins as possible, to prevent weakening of cusp structure and impingement on pulpal recessional lines. Since the buccal and lingual surfaces of the teeth converge gingivo-occlusally, the proximal cavity outline may also do so, for the reasons already explained, as well as for esthetic reasons. As is known, the areas of greatest susceptibility to a recurrence of decay are the bucco-gingival and linguo-gingival angles of the proximal marginal outline. The outline form here advocated readily allows of the extension of these angles into relatively immune areas, while the convergence of the buccal and lingual margins, which should follow the general contour and convergence of the buccal and

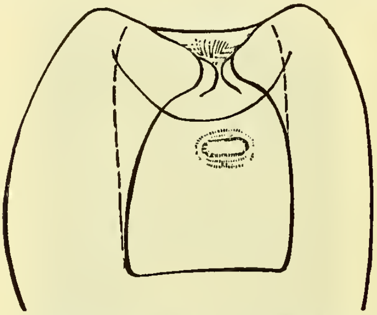


Fig. 409.—Diagram showing the parallel buccal and lingual margins formerly used (represented by dotted lines), and the converging buccal and lingual margins of the new cavity form. The amount of tooth structure conserved is apparent. The contact area (oval) is also shown. (Bronner.)

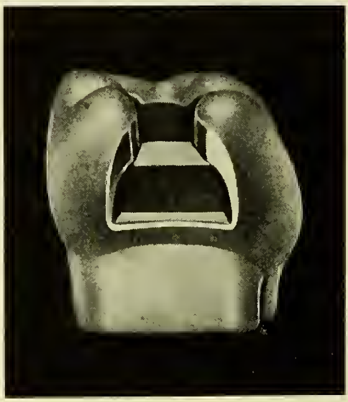


Fig. 410.—Class II cavity on a molar. New form.

lingual surfaces, still keeps these margins in safe areas in the region of the contact point, thus conserving much enamel in the areas out of contact buccally, lingually and occlusally to the contact point. Fig. 410. In markedly bell crown teeth, there is not so much gingivo-occlusal convergence of the buccal and lingual surfaces. However, the more pronounced convexity of the proximal surfaces and embrasures in these types of teeth and the smaller contact points still readily admit of the preparation of converging buccal and lingual outline form.

The enamel is thinnest at the gingival line and gradually becomes thicker as the occlusal surface is reached, consequently the dentin without its enamel covering represents a cone of even greater tapir bucco-lingually than that of the tooth surface. For this reason, the axial line angles and the buccal and lingual walls of the dovetail mortise portion of the proximal part of the cavity may converge even more than the proximal outline. Terminating as they do at the axio-pulpal line angle at the top of the step, this results in a shortening of the latter line angle as compared with the gingivo-axial line angle as seen in the old form of cavity. Thus is dentinal structure greatly conserved in this region, preventing encroachment on cusp structure and marked loss of the marginal ridge. As previously stated, resistance and retention form are by this means greatly increased, thus obviating the necessity for wide and deep occlusal steps. See Figs. 404 to 410.

In the Journal of Dental Research, Vol. 10, No. 1, February 1930, page 115, Doctor Bronner, in an article entitled "Engineering Principles Applied to Class II Cavities" presents some interesting illustrations indicating important reasons for adoption of converging buccal and lingual margins and walls in Class II cavities.

In Figures 411 and 412 I am reproducing these illustrations with the permission of Doctor Bronner. Figure 411 shows the usual parallel buccal and lingual margins and the converging margins of the new form. Figure 412, which is a double exposure, reveals the relationship of the buccal margin and wall of the old form to the underlying dentin. It also shows the converging buccal wall of the new form and reveals the amount of dentin preserved and the importance of so doing.

As the result of measurements of many teeth, he found a decided concavity of the dentin in the occlusal third of the buccal surfaces of lower bicuspids and molars which, as far as I am aware, has not been previously reported by other investigators. The presence of this concavity offers a strong argument against parallel buccal and lingual walls on lower posterior teeth, which procedure places the former directly in this area of weakened resistance to mechanical stress. Figure 413 well illustrates the danger of exposure of the pulp and the usual point of exposure, especially in mesio-occlusal cavities, where the mesial cornuae are usually well developed and persistent. Converging buccal and lingual walls greatly minimize this danger.

Adequate Access.—*It must not be supposed that the convergence of these walls will interfere with proper access to the proximal part of the cavity.* Too great a convergence should be avoided, else this undesirable condition will result. Adequate access should be obtained at all times, through proper separation of teeth and extension of cavity margins. If convergence of these outlines and line angles is properly provided for and not too much accentuated, and the correct buccal and lingual flare be given the remaining portion of the dentin walls intervening between the marginal outline and the axial line angles, an adequate view and ready access are obtainable for all further operative procedures incident to the filling of the cavity with gold or other material. It was previously stated that the average distance between the pulp horns in molars is 3.1 millimeters and that the average thickness of the enamel and dentin over the horns on the occlusal surfaces varies from 3.2 to 5 millimeters. The average thickness of enamel and dentin on proximal surfaces of these teeth is 2.5 millimeters. The proper preparation of this cavity, now to be described, should bring the buccal, lingual, axial and pulpal walls

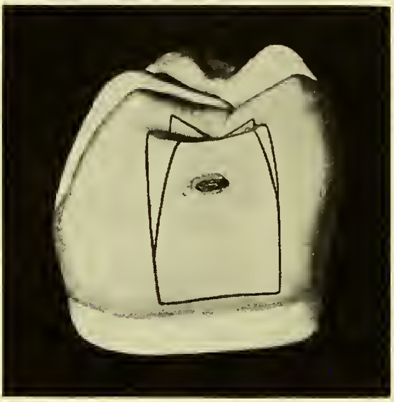


FIG. 411.—Molar showing parallel buccal and lingual margins to the outer sides and converging buccal and lingual margins of the new form. The contact area is also seen. (Courtesy of Dr. Finn J. Bronner.)

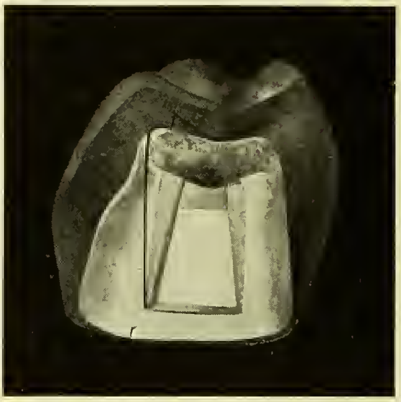


FIG. 412.—Double exposure showing relations of enamel and dentin, the dip in the dentin on the buccal side and the relative location of the buccal margin in the "old line" preparation, (shown as a black line) and the new form. (Courtesy of Dr. Finn J. Bronner.)

well away from encroachment on the cornuae, keep them within these measurements and at the same time afford sufficient access for operating Description of the preparation of a mesio-occlusal cavity in a lower molar is typical of the procedures applicable to cavities of this class on distal surfaces also, whether located on bicuspids or molars. Fig. 414.

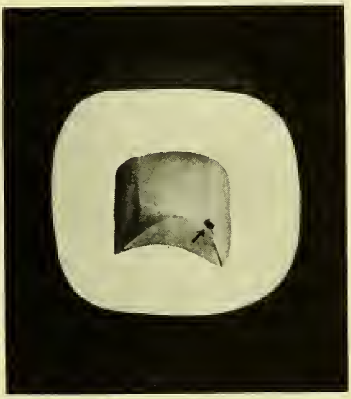


FIG. 413.—Showing cross section of a molar at the gingival line. The location, form and relative size of the pulp chamber are seen. The arrow points to the area of accidental pulp exposure in the "old line" class 2 cavity preparation. (Courtesy of Dr. Finn J. Bronner.)

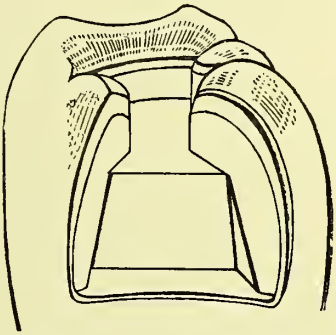


FIG. 414.—Mesio-occlusal cavity on a lower molar showing convergence of buccal and lingual walls and the dovetail proximal form.

PREPARATION OF A MESIO-OCCLUSAL CAVITY

Outline Form.—The case presents with a cavity of decay located slightly gingivally to the contact point, the mesial marginal ridge being intact, and the occlusal surface either free from decay or showing caries in the grooves and pits. The operation is begun by opening into the mesial pit, if not already decayed, with round bur number ½ and following it with inverted cone bur 33½. If the pit is already decayed, the round bur may be dispensed with. The outline form of the occlusal step may now be roughly established with the same instruments and technic described for class I cavities. The inverted cone bur 33½ is now sunk into the dentin and the cutting is gradually carried toward and under the marginal ridge until it sinks into the cavity in the proximal surface. Fig. 416. It is now drawn bucally and lingually until the opening is enlarged. If desired, a number 34 inverted cone bur or coarse cut pointed fissure burs 701, 702 or 703 may be substituted for this purpose and used until the dentin underlying the ridge is well undermined. In mesio-occlusal cavities in upper molars the same procedure will be carried out, starting in the central fossa and following along the mesial groove. In bicuspids, the cutting will be begun in the mesial or distal pit, while in distal cavities on upper molars the same procedure will be instituted, beginning in the distal fossa or pit. In either case, after undermining the marginal ridge, the next step consists of cutting a wedge through the enamel.

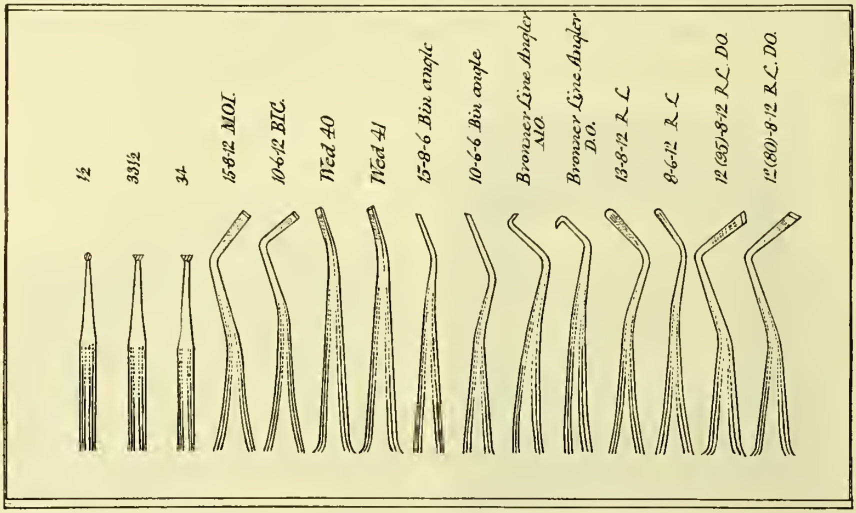


FIG. 415.—Instrument selection for preparation of Class II cavities.*

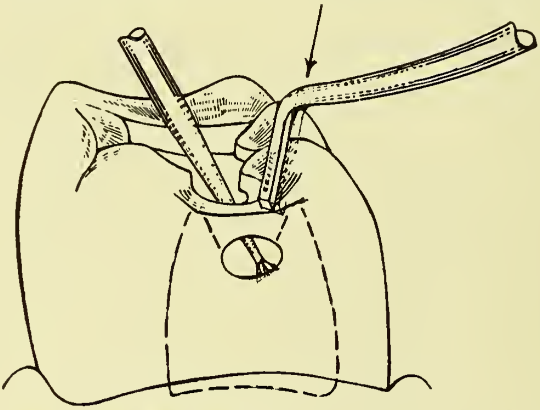


FIG. 416.—Removing the marginal ridge with inverted cone bur and enamel hatchet 15-8-12.

This is accomplished in molars with enamel hatchets 15-8-12 right and left; in bicuspids with 10-6-12 right and left enamel hatchets. In mesio-occlusal cavities Wedelstaedt chisels 40 and 41 or bin-angle chisels 15-8-6 (molars) or 10-6-6 (bicuspids) may occasionally be substituted to advantage, depending on location and angle of approach. With whatever instruments selected, the wedge is easily cut by placing its blade on the crest of the ridge and tapping it with a few sharp blows of the mallet, using the pair of instruments, one from the buccal and the other from the lingual aspect. The wedge is now enlarged to the desired size by undermining the underlying dentin with the 33½ inverted cone and chiseling away the enamel alternately, after which the occlusal outline form may be completed as described for class I cavities.

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*The drawings in this chapter were made by Dr. Victor Lane and are modified from an instrumentation chart designed by Dr. Finn J. Bronner.

Sufficient access has now been attained for establishing the outline form on the proximal surface. With inverted cone bur 33½ undermine the dentin at the dento-enamel junction, being careful not to cut too deeply in the axial direction. Now change to the previously mentioned enamel hatchets or chisels, depending on location, and cleave away the enamel bucally and lingually. Then scrape it away gingivally, alternating between the bur and the hatchets or chisels until the outline form is established as previously described, with its flat gingival margin extended into the gingival crevice and its converging buccal and lingual margins. The sequence as described has been (1) undermine the marginal ridge, (2) cut the wedge, (3) undermine the dento-enamel junction in the proximal portion, (4) chisel away the enamel bucally and lingually and (5) scrape the gingival wall and margin. The cavity is now ready for the next step.

Resistance and Retention Form.—This is obtained by flattening the pulpal wall and paralleling the axial walls in the occlusal part of the cavity, as previously described for Class I cavities; flattening the gingival and axial walls of the proximal portion and cutting the dovetail mortise form with its converging buccal and lingual line angles; and flaring out the remaining portion of the buccal and lingual walls in a gradual slope to the buccal and lingual margins. For this purpose, hand cutting instruments are indicated. Fig. 417. The gingival wall is flattened with enamel hatchets 15-8-12 right and left for molars, 10-6-12 for bicuspids, sharpened on the sides of the blades. The gingivo-axial line angle is made sharp and definite with the same instruments, and the sharply defined axial line angles are also cut and converged to the top of the occlusal step in a similar manner. Figs. 418 and 419. If desired, Bronner's axial line anglers (10-(95)-1-23 right and left), used with a circular gingivo-occlusal sweeping motion, with the second finger as a fulcrum may be used to scrape the axial wall, flattening it, and also to further perfect the axial line angles. These instruments are made in reverse form, one for mesial and one for distal cavities. By depressing the shank against the second finger as a fulcrum the blade is elevated and scraped over the axial wall and along the axial line angles until they are perfected. The edge and sides of the blades should be kept sharp for effective use. Figs. 420 and 421.

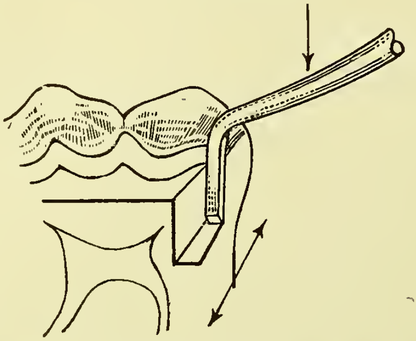

FIG. 417.—Shaping the proximal outline and flattening the gingival wall with enamel hatchet 15-8-12.

Convenience Form.—Every part of the cavity should now be inspected for convenience and ready access in placing gold foil. The extension of a mesial or buccal margin to enable the operator to secure a more direct line of approach for plugging gold may be considered advisable, and should be attended to at this time. Convenience points may also be prepared for starting gold by deepening the axio-pulpal point angles at

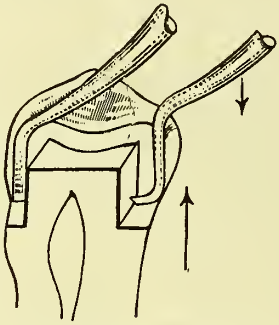

FIG. 418.—Cross section of an M.O.D. cavity in a bicuspid. Preparing resistance and retention form with enamel hatchet 10-6-12 and a Bronner axial line angler.

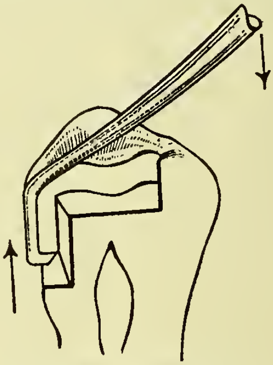

FIG. 419.—Use of Bronner axial line angler in proximal part of a Class II cavity in a bicuspid.

the extremity of the step and the bucco-axio-gingival and linguo-axio-gingival point angles on the gingival wall. These may be prepared with a 33½ inverted cone bur, as described in the previous chapters. Fig. 422. However, in the cavity here advocated, if the dovetail mortise form is properly prepared, little if any additional cutting is necessary in the

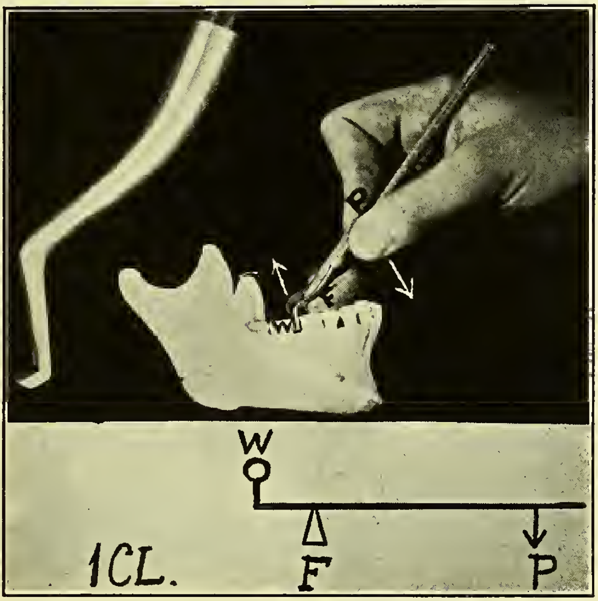

FIG. 420.—Use of the Bronner axial line angler in the proximal part of a mesio-occlusal cavity in a lower molar. A modified pen grasp with rest on the second finger is used. A lever of the first class is seen.

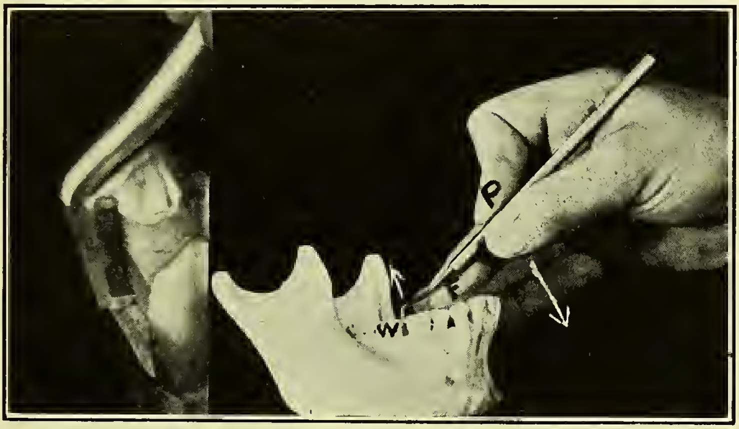

FIG. 421.—Bronner axial line angler used in a disto-occlusal cavity. Lever of the first class.

gingival point angles. If needed, it may often be done with the hand instruments primarily used, rather than the bur.

Removal of Remaining Decay.—The cavity should now be inspected for any remaining traces of decay, which, if found, should be removed with spoon excavators 13-8-12 or 8-6-12 right and left. Under ordinary circumstances, all decay will have been removed during the performance of the preceding steps. If it is found necessary to remove traces of it at this time, the walls should, following its removal, be again squared up, flattened and made smooth. In cases of deep and extensive cavities, it will often be better to place this step as second in the preparation and remove the decay fully before attempting other procedures. Especially is this important where pulp exposure is suspected.

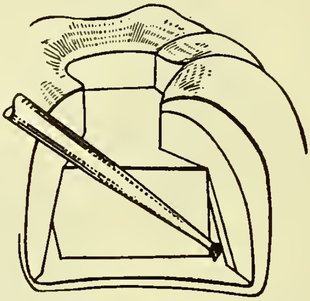

Fig. 422.—Deepening the ginigval point angles with a 33½ inverted cone bur.

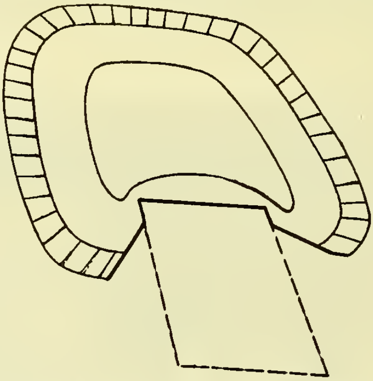

Fig. 423.—Diagram of a cross section of a molar in the gingival third, showing the pulp chamber, inclination of the enamel rods and the form of the proximal portion of a Class II cavity. The buccal and lingual walls of the dovetailed part of the proximal portion next to the axial wall are parallel in a mesio-distal direction. This dovetailed form is placed between the pulpal extensions (the danger line), and the buccal and lingual dentin walls then flare out to meet the enamel walls in the same plane. The preparation of the enamel wall on the left is correct, while the supplementary bevel shown on the right is unnecessary.

Finishing the Enamel Walls.—The enamel walls should now be carefully gone over with planing instruments and thoroughly smoothed. The preparation of the occlusal enamel margin is accomplished in the same manner and with the same instruments as described for Class I cavities. Owing to the strong buccal and lingual inclination of the enamel rods on the buccal and lingual margins of the proximal portion, no additional bevel of these margins is necessary. In fact, an additional or supplementary bevel here would produce too thin a margin to the filling when it is built over them, resulting in a feather edge, which would be likely to break away, become easily marred, or be left with an irregular, ragged outline after polishing. All that is usually necessary, then, is to plane these margins smooth, following the lines of cleavage of the rods in these positions. Fig. 423. The best instruments for this purpose are the 15-18-12 right and left enamel hatchets, the direction of cutting being occluso-gingivally (Fig. 424). The gingival margin is planed and thoroughly smoothed with the gingival margin trimmers 12-(80)-8-12 and 12-(95)-8-12 right and left. Fig. 424. The 12-(80)-8-12 instruments are applicable to mesial cavities and the 12-(95)-8-12 to distal cavities. The thickness of the enamel in this locality is about 0.5 millimeters, and the rod inclination averages 6 to 10 centigrades gingivally. Owing to its thinness, it should be bevelled its full width here. Fig. 425. The angle of the blade of the gingival margin trimmers is designed to automatically give the correct bevel, following the inclination of the rods. The gingivo-axial angles of the marginal outline should not be left acute. They should be well rounded and care should be taken to see that they

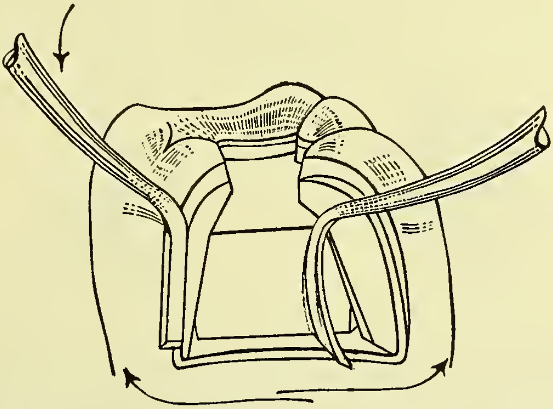

FIG. 424.—Finishing the buccal and lingual enamel walls with enamel hatchets 15-8-12 and the gingival wall with gingival margin trimmers.

have been extended well out into the embrasures, where they will be least susceptible to a recurrence of decay.

Where gingival margins of either class II, III, IV or V cavities extend in close proximity to the gingival line, special care should be observed in their preparation. According to Hopewell-Smith, Dental Cosmos, Vol. 69, No. 5, May 1927, pp. 470, the enamel overlaps the cementum in the gingival region in only 0.5% of cases; is overlapped by it in 60 to 65%; just touches it edge to edge in 30%; and in 5 to 10% of cases, the cementum fails to meet the enamel, the dentin being exposed

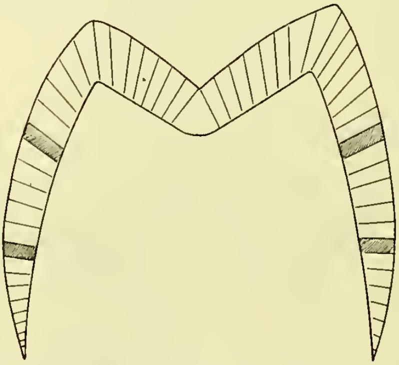

FIG. 425.—Comparative thickness of enamel, and rod inclination on different parts of the crown of a molar. The enamel is thinnest at the gingival line and thickest at the cusps. The rod inclination is toward the gingival in the gingival third, perpendicular to the dentin at the junction of the middle and gingival third. At the junction of the middle and occlusal thirds the inclination averages 8 to 12 centigrades toward the occlusal, while surrounding occlusal pits and fissures the rods incline strongly toward each others.

and unprotected. In view of these facts, there is always great danger, when operating in this region, of leaving weak and unsupported enamel rods on gingival margins, or of leaving exposed and unprotected areas of dentin subject to decay, thermal and tactile impressions. The additional dangers of damaging Sharpey's fibres and other structures of the cementum, or of producing inflammation or destruction of the alveolo-dental periosteum should constantly be borne in mind. These dangers may arise from careless preparation of gingival cavity margins, polishing of fillings, application of clamps and separators and similar procedures.

Toilet of the Cavity.—The procedures incident to the toilet of the cavity have been fully described in the previous chapters.

PROCEDURES IN SPECIAL CASES

In preparing Class II cavities in bicuspids, the small size of the tooth necessitates careful cutting, to avoid exposure of the horns of the pulp.

The distance between the horns in these teeth is much less than in molars, averaging 2.5 millimeters, and they are comparatively closer to the surface. This necessitates narrower gingival walls mesio-distally and shallow cavities occluso-gingivally, in the step portion. The average depth of occlusal steps in the central portion of these teeth should be about 1.5 millimeters. If the stress is great, they can be carefully cut to 2 millimeters in depth in adult teeth. The same may be said of the molars. Rarely will it be necessary to make them deeper in molars than 2.5 millimeters, and then usually only in cases of deep caries involvement. The mesio-distal width of the gingival wall in bicuspids may average 1 millimeter and in molars 1.5 millimeters.

In large decays, where the marginal ridge is already extensively undermined and caries is also present on the occlusal surface, the ridge may sometimes be removed at once with a bin-angle chisel, Wedelstaedt's chisels or the enamel hatchets. In these cases, extensive cutting will sometimes have to be resorted to for the removal of decay and to obtain strong enamel walls. The buccal and lingual margins may have to be extended radically and sometimes a buccal or lingual cusp removed. These procedures are under no circumstances to be considered as extension for prevention operations, but are resorted to as a necessity for the removal of decay and for the strengthening of enamel walls. In mesio-disto-occlusal cavities (M.O.D.), the various steps are performed in a manner similar to those for ordinary Class II cavities. Where caries involvement in the occlusal surface is extensive, necessitating wide bucco-lingual extensions of the step, the attachment of the buccal and lingual cusps, especially in bicuspids, may be badly weakened, rendering them liable to fracture under the stress of mastication. Under these circumstances, it may be considered advisable to remove a portion of the cusps and restore them with the filling material. In large cavities, the removal of decay should often precede the preparation of the resistance and retention form. In cavities on distal surfaces, the use of the contra-angle hand piece will often be necessary, where the bur is resorted to.

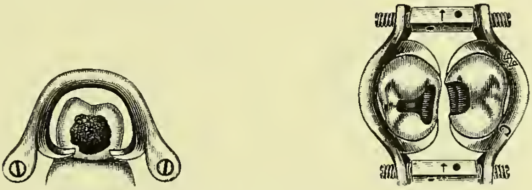

FIG. 426.—Perry separator in position on bicuspids.

However, these cavities, as in all Class II cavities, are prepared largely with hand cutting instruments. It is always well to remember that extensive cutting of buccal and lingual margins may frequently be avoided by adequate separation of proximating teeth and building contact points over-full, thus drawing these margins out of contact with each other and placing them in relatively immune areas through separation, rather than cutting. In all proximal cavities, ready access may be obtained through separation. For this purpose, the separator may often be placed in position early in the operation. Fig. 426.

PREPARATION OF CLASS III CAVITIES

These cavities, owing to the triangular form of the proximal surfaces of the anterior teeth on which they are located demand the formation of a triangular, box-shaped cavity with converging labial and lingual walls, rather than the square-formed box indicated in other localities. The small size of the tooth and the close proxmity of the pulp to the surface, as well as the necessity for operating in close interproximal spaces, require the use of small instruments and careful cutting to avoid pulp exposure, damage to the proximating tooth and to the interproximal gingival tissues. Approach to the cavity is obtained through the embrasure, either labially or lingually, depending on the extent of the decay. In some instances, after application of the rubber dam, the separator should be carefully placed at once and the teeth drawn apart until sufficient access is gained. Fig. 427. The necessary access should be obtained through separation and not through extension of cavity margins. Care should be observed to avoid exposure of gold on labial surfaces. The labial enamel plate is relatively thick on these surfaces, and in some instances a portion of it unsupported by dentin may be left, to avoid undue display of gold. However, in no instance should unsupported enamel, partially affected by backward decay be left in position. Neither should thin enamel, through which gold will be reflected, be left. Thin or affected enamel will likely be fractured during or soon after introduction of the filling, or if not, the color of gold showing through will be more objectionable than uncovered gold. Labial and lingual margins should be cut away from contact with the proximating tooth. In small Class III cavities, it is often possible to do this and at the same time avoid display of gold. If the extent of caries demands further extension of the labial margin, it will often be better to carry it out and make a slight display of gold, rather than to extend it only to the point where the filling will show as a thin line of metal. This latter procedure will often throw the gold in shadow and cause it to appear dark and objectionable, especially under artificial light. The average depth of these cavities in the dentin should be 1 millimeter. The average thickness of enamel and dentin on proximal surfaces of upper anterior teeth is 2.3 millimeters on centrals and cuspids and 2 millimeters on laterals. On lowers it varies from 1.8 millimeters on centrals and laterals to 2.1 millimeters on cuspids.

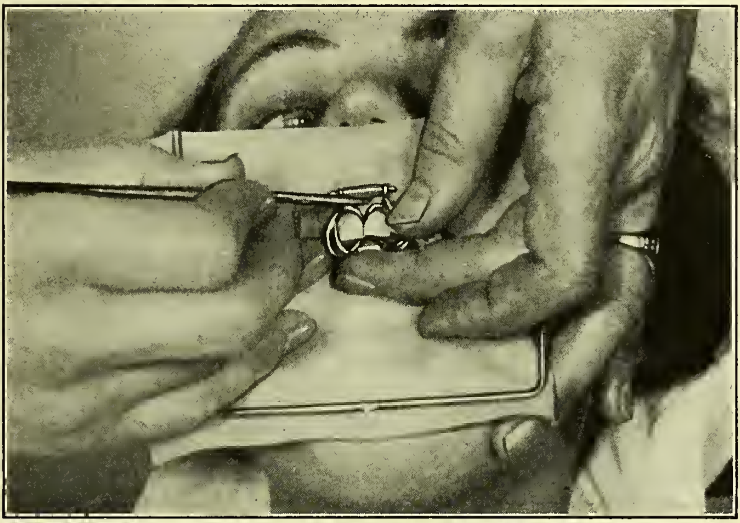

FIG. 427.—Application of the Perry separator to the central incisors.

SMALL CLASS III CAVITIES

The case presents with a small area of decay, sometimes hard to discern, located just gingivally to the contact point. Early discovery and filling of these decays is important, to avoid extensive cutting and display of filling material.

Outline Form.—The rubber dam and separator should be applied at once and sufficient separation for access be obtained. Begin on the labial margin of the cavity with hoe 8-3-6, used as a chisel. With hand pressure, chip away the enamel in small pieces, working from the surface toward the cavity. Use Relation number 1 (see previous chapter) and keep the instrument under control, so that it will not slip into the cavity and cause pain. Fig. 429. Only the thinnest portion of enamel should be removed with this instrument. Now changing to Wedelstaedt chisel number 40, straight chisel number 10, or bin-angle chisel number 10-5-6, continue the cutting on the labial margin until the enamel is cut back to sound dentin, and the cavity of decay is fully exposed. The direction of the cutting with the chisel should be toward the gingival and along the length of the enamel margin. In small cavities of this type, very little exposure of the labial margin will be required. All that will usually be necessary will be to bring the labial margin away from contact with the proximating tooth, leaving it well into the embrasure. As much of the gingival margin as can conveniently

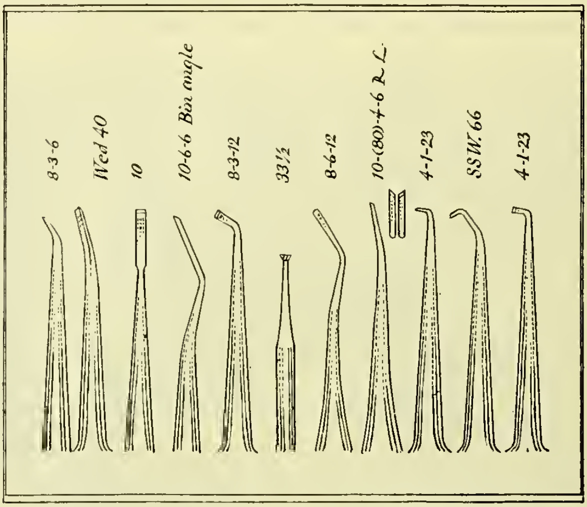

FIG. 428.—Instrument selection for Class III cavities.

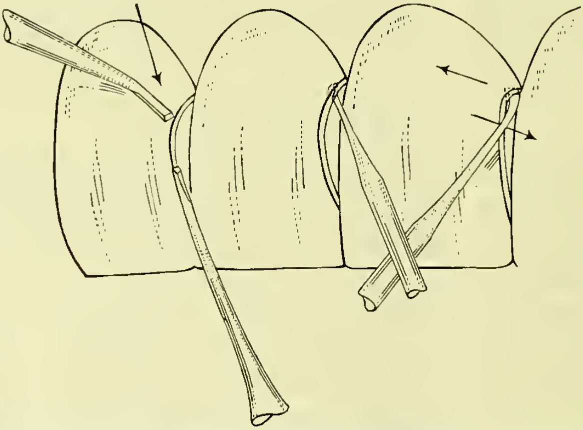

FIG. 429.—Steps in preparation of the outline form for Class III cavities, using consecutively hoe 8-3-6, Wedelstaedt chisel 40, inverted cone bur 33½ and hatchet 8-3-12.

be reached with these instruments should also be removed. Now change to inverted cone bur 33½ and undermine the dentin underlying the gingival enamel. The bur should be held close under the enamel wall and the cutting done into the dento-enamel junction. Now with hatchet 8-3-12 remove the unsupported enamel. If necessary to extend further, use the bur and hatchet alternately until the gingival margin has been carried to its proper location. In using the hatchet, it should be rested against the proximating tooth or the one operated on, depending on the approach, as a fulcrum, and the enamel should be chipped off into the cavity in small pieces, scraping labio-lingually. Now the lingual margin may be chipped away and extended with hoe 8-3-6 or 8-3-12 and the chisels previously mentioned, working from the lingual aspect. The labio-gingival and linguo-gingival angles should be extended sufficiently to bring them well into the labial and lingual embrasures. This may be done, first with the inverted cone bur 33½, undermining the dentin, and then chiselling the enamel with the previously mentioned cutting instruments. For extending the labio-gingival angle the bur may be inserted from the lingual, and for the linguo-gingival angle from the labial. With the hand cutting instruments, the labio-gingival angle may be chiseled from the labial, and the linguo-gingival angle from the lingual approach. All operating from the lingual approach should be done through the use of the mouth mirror. The incisal angle should next receive attention and should be extended until sound enamel is reached, with the same instruments. On completion, the outline form should be triangular in shape with rounded, not sharp, angles.

Resistance and Retention Form.—Special resistance form is not needed. However, the gingival wall should be made flat in the mesiodistal direction and be cut either flat labio-lingually or made to follow the curvature of the marginal gingiva. In these small cavities, it is usually not necessary to curve it. The gingivo-axial line angle should be well emphasized at the junction of the gingival and axial walls, and the labio-axial and linguo-axial line angles should now be started and extended a short-distance at this time. For flattening the gingival wall and forming the line angles mentioned, the Woodbury-Crandall angle forming instruments 10-(80)-4-6 right and left may be used. However, they should be used only in this portion of the cavity and for starting the axial line angles. The latter angles should be carried incisally a distance of about one-fourth their ultimate length, with these instruments. The labio-gingivo-axial and linguo-gingivo-axial point angles may now be further sharpened, if necessary, with inverted cone bur 33½, the first from the lingual and the second from the labial approach. Now with hoe 4-1-23, used with a scraping motion, the labio-axial and linguo-axial line angles should be further cut and extended into the incisal angle of the cavity, making them definite and sharp. They should be cut into the dentin and not close enough to the enamel to undermine it. Fig. 430. Hoe 4-2-23 will often be found too long for this purpose in small cavities, unless its blade has been shortened by frequent sharpening. The incisal point angle should now be deepened in the incisal direction by placing the blade of S.S.W. hoe number 66 or 70 in it and scraping out the dentin until it is sufficiently deepened. Fig. 431. Now place the blade of hatchet 4-1-23 in this angle and, by a sweeping rotary motion, further enlarge and deepen the point angle labially and lingually until it is perfectly retentive in form and large enough to receive the nib of the plugging instrument. A bur should never be used in preparing the incisal point angle. Care should be observed not to cut this point angle so close to the enamel as to weaken it. Fig. 432. On its completion, it should have been deepened incisally, slightly axially, and present slight labial and lingual grooves running up to join the labio- and linguo-axial line angles. The axial wall may now be gone over with hoe 4-1-23, smoothed and made convex labio-

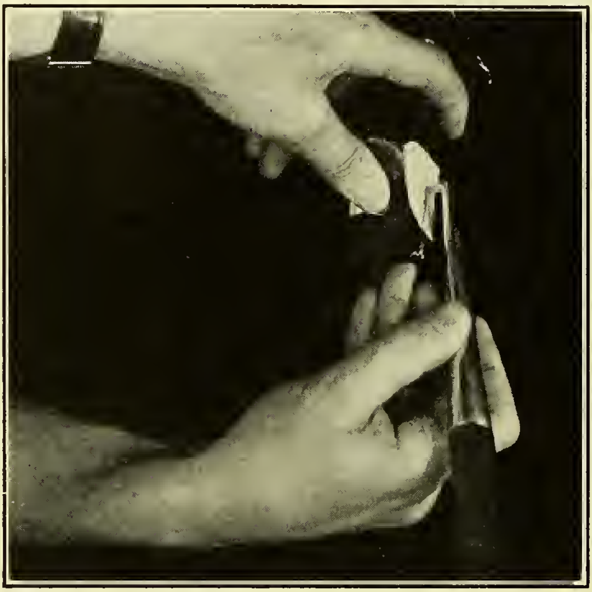

FIG. 430.—Preparing the labio-axial and linguo-axial line angles with hoe 8-1-23. (Courtesy of Dr. Finn J. Bronner.)

lingually to follow the curvature of the underlying pulp chamber. If necessary, the labial and lingual walls may also be further smoothed with the same instrument.

Convenience Form.—For starting gold, the gingival point angles may now be further accentuated with inverted cone bur 33½, cutting largely at the expense of the axial walls and not of the gingival wall. If additional access is needed for filling, it may be obtained through increased separation or by further extension of the lingual margin.

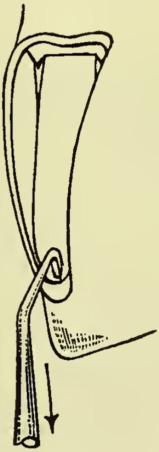

FIG. 431.—Starting the preparation of the incisal point angle with excavator No. 70, S.S.W.

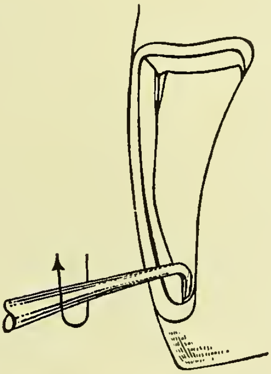

FIG. 432.—Use of hatchet 4-1-23 in completing preparation of the incisal angle.

Removal of Decay.—All decay will usually have been removed during the performance of the preceding steps. The cavity may be now thoroughly inspected and if any traces are found they should be removed.

Preparation of the Enamel Wall.—In the preparation of the enamel wall, it is well to remember the direction of the rods in the various localities. These incline 6 to 10 centigrades gingivally in the gingival region and the enamel here averages 0.5 millimeters in thickness. In the middle third, the rods are perpendicular to the surface of the dentin, while, at the junction of the middle with the incisal third they incline incisally from 8 to 18 centigrades. Their inclination increases more and more as the angle is approached and is greater on distal surfaces. Fig. 433. Bearing these facts in mind, the gingival enamel wall should be bevelled its entire thickness, following the lines of cleavage of the rods, on an average of from 6 to 10 centigrades. This may be readily accomplished with Woodbury-Crandall angle formers 10-(80)-4-6 right and left, the gingival margin trimmers usually being too bulky and awkward for small cavities of this type. The labial and lingual margins should now be planed and smoothed their entire thickness, with Wedelstaedt chisel 40, the movement of the instrument being along the length of the enamel walls. If preferred hoes 8-3-6 and 8-3-12 may be used for the same purpose. The angles joining the labial and lingual enamel walls with the gingival wall should be planed slightly rounded, no matter how sharp the angles in the dentin may be. At the incisal portion, the enamel wall must be bevelled full width strongly toward the incisal, following the cleavage lines (8–18 centigrades). The inclination of the rods is usually greater on distal than on mesial surfaces of anterior teeth. Wedelstaedt chisel 40 or hoes 8-3-6 and 8-3-12 will be indicated here. The toilet of the cavity should now be made, when it is ready for filling with cohesive gold.

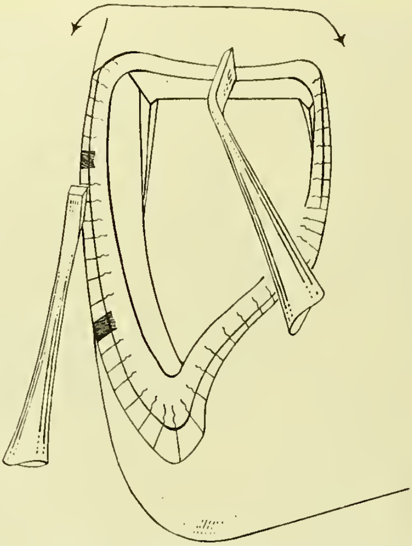

FIG. 433.—Showing inclination of the enamel rods on the proximal surface of anterior teeth and the preparation of the enamel wall of a Class III cavity with a Wedelstaedt chisel No. 40 and a gingival margin trimmer. The inclination of the rods at the junction of the middle with the incisal thirds is approximately 8 to 18 centigrades.

MEDIUM SIZE CLASS III CAVITIES

The principles underlying the preparation of these cavities are the same as those for small cavities already described. Fig. 434. The case presents with a larger area of decay, which has usually involved a larger extent of the labial and lingual plates. Great care should be observed to preserve as much of the labial plate as conditions will permit, in order to avoid display of gold. Adequate separation should be accomplished at once. In many instances, it will be better to extend the lingual margin strongly to the lingual and to prepare the cavity so that the line of approach for filling will be from the lingual, rather than the labial direction. The labial margin should never be extended merely for convenience in filling. However, if it is involved from extension of decay, it must be removed and, under these circumstances, a labial approach may be used. If the lingual approach is used, much of the preparation and filling will be done with the assistance of the mouth mirror, thus viewing the reflected image. This procedure will be awkward to the beginner, since the movements of the instruments will appear reversed. It should be practiced until efficiency is gained in this manner of operating. Elevation of the chair and tilting of the patient backward to gain direct approach should not be countenanced. Fig. 435. Owing to the rather indefinite direction of travel of the rods on the lingual marginal ridge, this margin should usually be carried well over the ridge and established on the lingual surface, where better and surer cleavage lines and a better finishing margin may be obtained. The margin should not be gradually curved over, but should be extended over for nearly its full length, thus being made a straight, rather than a

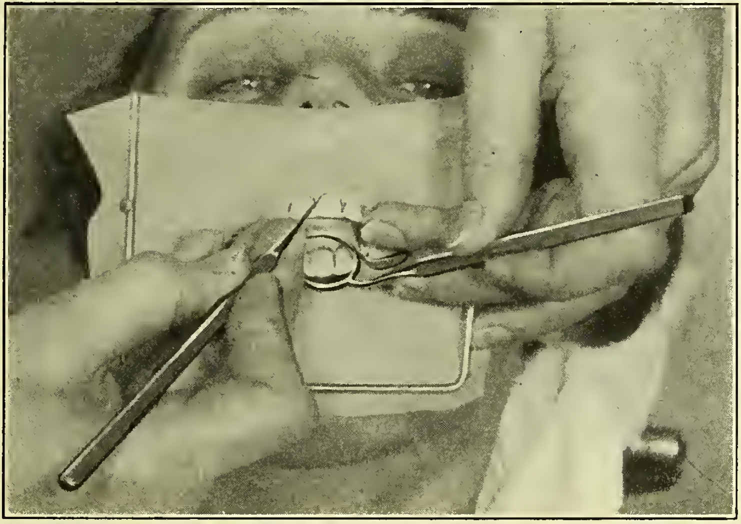

FIG. 434.—Operating on a Class III cavity. The rubber dam is well applied, the mouth mirror is correctly used and a pen grasp with rest on the second finger is seen.

curved margin, and following the line of the marginal ridge. However, its junction with the gingival and incisal margins should be slightly rounded.

In some instances, where the decay is deep, it may be better to remove it immediately with spoons 8-6-12 right and left, on completion of the outline form, rather than waiting to establish the internal form of the cavity.

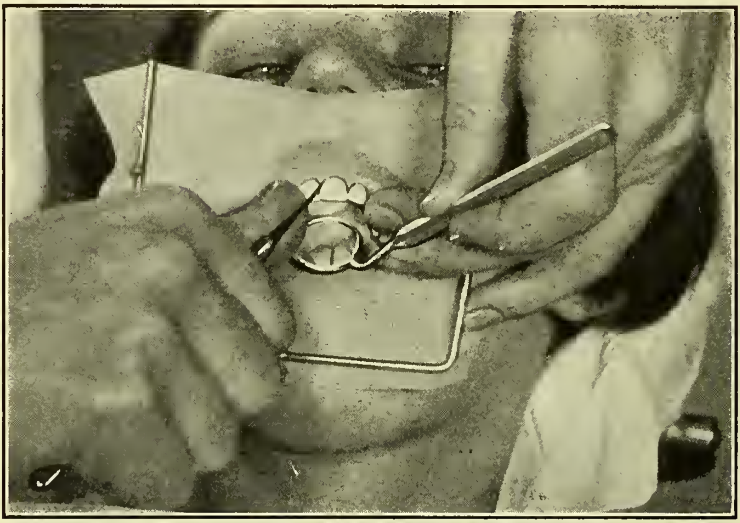

FIG. 435.—Operating on a Class III cavity. The palm-thumb grasp and use of the mouth mirror are well shown.

The outline form, resistance, retention, and convenience forms are prepared with the same instruments and technic as utilized for the smaller cavity previously described. The triangular box with flat gingival wall, definitely defined line and point angles, convex axial wall and characteristic incisal angle are completed, as already described. The gingival margin and wall in many instances had better be cut to follow the curvature of the marginal gingiva. If the contact point is not too close to the incisal angle of the tooth, it will sometimes be well to cut it away and extend the cavity incisally, in order to place the incisal margin out of the area of susceptibility. Owing to the shape of the tooth, this may often be better accomplished on distal than on mesial surfaces. On the latter surfaces the contact point will often be found so close to the incisal angle that its removal will not be justified. In these cases, it will usually be better to increase the separation and establish a new contact on the filling, thus placing the incisal margin in an area of relative immunity. The preparation of the enamel walls is accomplished in the same manner and with the same instruments as described for small cavities of this class.

LARGE CLASS III CAVITIES

In these cases much of the proximal surfaces of the tooth will be involved. The decay will be so deep and extensive that exposure of the pulp is feared and the labial and lingual enamel plates are badly weakened. Much of the preliminary enamel cleavage and removal of decay may be accomplished before placing the rubber dam and separator in position. It will be necessary to extend the cavity well over in the labial and lingual as well as gingival and incisal directions. With the dam in place the outline form should now be extended until sound dentin is reached, after which the remaining decay should be carefully removed with spoons 8-6-12, avoiding pulp exposure if possible. The internal parts of the cavity should now be prepared with the previously mentioned instruments, curving the axial wall strongly labio-lingually to avoid pulp exposure, and curving the flat gingival wall to follow the convexity of the gingival line. The approach will be from both labial and lingual directions, owing to involvement of the labial and lingual enamel plates. The axial line angles should be strongly accentuated and, if possible, ledges should be cut along the labial and lingual walls for convenience in packing gold and to increase resistance form. The incisal retention should be made as strong as conditions will permit, after which the enamel walls should be prepared, the cavity inspected for remaining decay and the toilet completed.

PREPARATION OF CLASS IV CAVITIES

In these cavities the location or extent of the decay on the proximal surfaces of the incisors or cuspids has either destroyed the incisal angle or it becomes necessary to remove it during their preparation, owing to its weakened condition. Cavities of this type are met with more frequently on mesial than on distal surfaces. This is due to the fact that the mesial surfaces of these teeth are flatter than the distal surfaces and the contact points are nearer the incisal angle. In some cases, moderate size cavities, beginning slightly gingivally to a contact point located closely to the incisal angle, will so weaken it that its removal will be required. In the majority of cases, however, the decay is deep and widespread, involving much of the proximal surface and burrowing under the labial and lingual enamel plates to such a degree that marked extension of these margins will be required to reach sound dentin.

In the former instance, a cavity of moderate size may be prepared on the proximal surface, which will not necessarily involve a great deal of the mesial or distal lobe of the tooth. In the latter, a great extent of this lobe may be involved.

Preparation of the Proximal Portion.—The technic of the preparation of the proximal portion is about the same as that described for Class III cavities, except that here the incisal angle must be removed. The same instruments as previously described are used. Effort should be made to preserve as much of the labial surface of the tooth as conditions will admit. However, weakened enamel plates, unsupported by dentin, must be extended out for reasons of strength, regardless of the extensive cutting required. In the smaller types of involvement, the labial and lingual walls may be kept well on to the mesial or distal lobe and away from the labial developmental groove. In these cases the margins should usually follow the same direction as the labial groove. If they do not, and are allowed to travel toward or gradually approach the incisal angle, a sharp or obtuse angle will be formed here which will be mechanically weak and artistically poor in form. If from extensive caries involvement these margins approach very closely to the developmental groove, they should be extended into or past it, else they will be left in a relatively weak area. The gingival seat should be flat mesiodistally, should follow the curvature of the gingival line labio-lingually, and the axio-gingival angles of the outline form should extend well out into the embrasures. In cavities of the larger type, great attention should be given to the resistance and retention form in the gingival portion. The labio-lingual convexity of the gingival wall will afford a larger surface area for the seating of the filling, and further deepening of the gingival point angles will allow for increased retention. The axial line angles should be well marked and every effort made to secure additional anchorage by well prepared labial and lingual walls. The labial and lingual walls and the labio-axial and linguo-axial line angles will converge labio-lingually as this angle is approached, but will not meet, as they do in Class III cavities, at the incisal angle. No effort should be made to prepare a point angle in this location, since retention must be provided for here by an incisal or lingual step.

The Incisal Step.—In the smaller types of cases, when the labial and lingual margins have not been extended into the labial developmental grooves, but involve only a portion of the mesial or distal lobe, the step may be carried over to the center of the incisal edge of the central lobe. In the larger cavities it should be carried across the central lobe and past the opposite developmental groove (mesial or distal). On abraded incisal surfaces, where the dentin is exposed, it will be better to include the entire abraded area and extend over to the enamel of the opposite angle.

The danger of accidental exposure of the pulp should be constantly borne in mind here. The horns and recessional lines of the pulp extend toward the incisal angles. The pulp is nearer these angles and the incisal surface in the young than in adults and farther away in the aged. Also, it is closer to the surface in thin teeth—the thinner the tooth labio-lingually, the closer to the incisal surface. In adults the average distance from the incisal edge to the pulp is in upper centrals and cuspids 4.7 millimeters; in laterals 4.5 millimeters. On lower teeth the distance varies from an average of 3.7 millimeters on centrals and laterals to 4.7 millimeters on cuspids. The amount of dentin intervening between the labial and lingual enamel plates in thin teeth is usually very small. For this reason and on account of the necessity for protecting these plates with underlying dentin, as well as on account of the danger of pulp exposure, the use of the incisal step is often contraindicated in this type of tooth. Also, the resultant necessity for the removal of much labial enamel to obtain sufficient depth for the step will involve inartistic gold display. In many instances, the lingual step form had better be

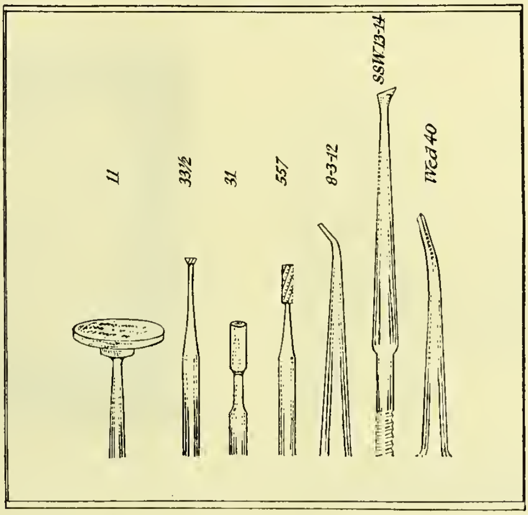

Fig. 436.—Instrument selection for preparation of the step in Class IV cavities.

adopted. In some cases, to avoid the necessity for building up the incisal portion with gold to the length of adjoining teeth, it may be better to grind the incisal edges of these latter teeth, shaping them to corresponding length with the tooth operated upon. This "truing up" process should not involve the entire thickness of enamel on the adjoining teeth.

Technic for Incisal Step.—First, grind off that portion of the incisal edge to be included in the step with stone number 11 S.S.W., for a depth of from 1 millimeter to 1½ millimeters, depending on the thickness of the incisal edge. Fig. 437. Now, with inverted cone bur 33½, cut a groove into the dentin between the labial and lingual enamel plates extending full length of the step. The bur should be started at the beginning of the step, sunk into the dentin while being held parallel with the long axis of the tooth and then drawn incisally, repeating this procedure until the groove is cut full length of the step. It should be held close to the lingual enamel, preserving as much of the dentin against the labial enamel as possible. Now, changing to stone number 31 S.S.W., remove with the flat end of the stone the lingual enamel to the depth of the groove previously cut. Then with inverted cone bur 33½ deepen the groove again, being careful to leave the dentin supporting the labial enamel. These

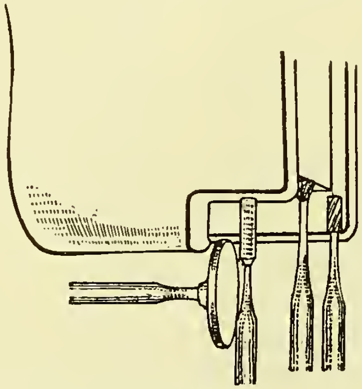

Fig. 437.—Preparation of the incisal step, using stones No. 11 and 31, S.S.W., and burs 33½ and 557.

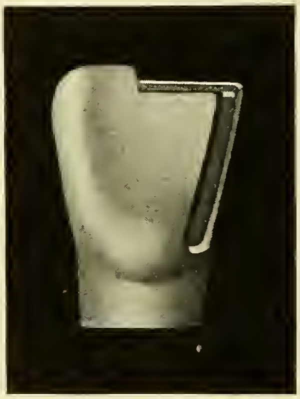

Fig. 438.—Incomplete preparation of a Class IV cavity, lingual view. The incisal angle has not been sufficiently removed, thus leaving it mechanically weak. The gingival wall should be broader mesio-distally, more of the lingual enamel of the incisal step should be removed and the step should be deepened.

procedures are continued alternately until a groove of sufficient depth and width has been obtained into which a sufficient body of gold may be built to securely anchor the incisal portion of the filling into place. Fig. 438.

The extent of the cutting will depend on the thickness of the tooth labio-lingually and the amount of dentin between the labial and lingual enamel plates. The depth of the groove below the lingual enamel plate should at least equal its width, or be slightly greater. Too much depth may endanger the pulp, increase the difficulties in filling, or subject the pulp to thermal influences. The groove should now be squared out, its floor made flat and its lateral walls parallel, with fissure bur 556 or 557. No undercuts are necessary. A little broadening and rounding away at the junction of the step with the proximal portion of the cavity will allow increased body of gold and strengthen the filling in that location. For starting gold, a small pit may be cut with inverted cone bur 33½ into the dentin at the extremity of the step. The enamel rods bordering the step incline incisally. With Wedelstaedt's chisel number 40 or bin-angle 15-8-6 they may be bevelled outward 3 centigrades, planing all around the cavo-surface in the direction of the marginal outline of the step, when, after performing the toilet, the cavity is ready for filling. Fig. 439.

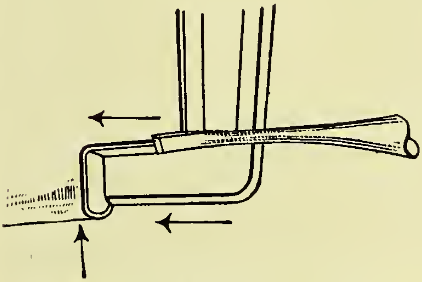

FIG. 439.—Finishing the enamel wall of the incisal step with Wedelstaedt chisel No. 40.

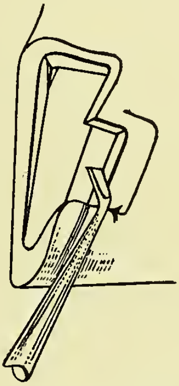

FIG. 440.—Preparing the resistance and retention form of the lingual step with hoe 8-3-12.

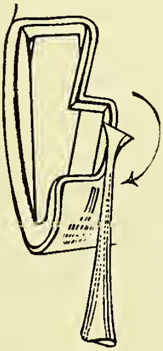

FIG. 441.—Finishing the enamel wall of the lingual step with hard bits Nos. 13 and 14.

The Lingual Step.—In many instances, especially in thin teeth, this provides a safer anchorage, with less cutting, than the incisal step. Also, it avoids display of gold across the incisal surface, since the labial enamel plate is left intact, the step being cut over on to the lingual surface of the tooth. The preparation of the proximal portion of the cavity is the same as already described and the same technic is followed. After this, a step is cut with inverted cone bur 33½ over into the central fossa of the lingual surface of the tooth. This step should be wide and deep enough to accomodate a sufficient body of gold for strength, and be as near the incisal edge as conditions will admit, to provide against the leverage to be applied against the filling in mastication. The further away it is placed from the line of stress, the less effective it will be. Fig. 440. The nearer it is to the incisal angle the greater will be the tendency to weaken this angle. Consequently, great judgment will have to be used in locating it in the proper position. Usually it will be placed slightly nearer to the incisal angle than to the gingival margin. Its depth should not be so great as to endanger the pulp or subject it to thermal changes, being usually not more than 1 millimeter into the dentin at its deepest parts. It should be made in dovetail form, being slightly wider gingivo-incisally at its extremity than at its beginning. After its outline has been cut with inverted cone bur 33½ its floor should be flattened and its lateral walls made parallel with hoe 8-3-12, cutting with the edge and sides of the blade, after which its enamel walls should be bevelled outward 3 centigrades with S.S.W. hard bits 13 and 14 or hoes and hatchets 8-3-12. If desired, a small pit may be cut in one of its angles for convenience in starting gold. Fig. 441.

In modern dental practice, teeth with Class IV cavities and extensive Class III cavities had often better be filled with porcelain inlays or cut down and porcelain jacket crowns adapted. This subject is fully discussed in the chapters on Filling Materials and Ceramics.

PREPARATION OF CLASS V CAVITIES

These are smooth surface cavities located on the gingival third of labial, buccal and more rarely, lingual surfaces of the teeth. Gingival third cavities on the lingual surfaces usually result from the wearing of prosthetic or orthodontic appliances and are so rare that they need only to be mentioned here. The technic of their preparation is so similar to that for gingival third cavities on labial and buccal surfaces that it will not be necessary to give a separate description of it.

The earliest evidence of approaching cavity formation in Class V cavities is hypersensitiveness and a whitish, chalky appearance of the enamel close to the marginal gingiva. This latter symptom will sometimes escape attention unless the saliva is excluded and the surface dried. If discovered in the early superficial stage, often the surface may be given prophylactic treatment and be highly polished, when if the patient is instructed as to its proper care, cavity formation may be prevented. If the whitish area shows signs of penetration, it will be necessary to prepare a cavity for filling. Often the case will present with one or more small carious areas in the center of the gingival third of the labial or buccal surface, with extensions mesially and distally of a chalky, whitish line running along in close proximity to the marginal gingiva. In other cases, a well defined cavity, which has penetrated the enemal is in evidence. In unclean mouths, the cavity may extend beyond the axial line angles and unite with decay on the proximal surface.

Hypersensitivity, a tendency to extend mesially and distally toward the axial line angles of the teeth and the presence of hyperemia or inflammation and tenderness of the marginal gingiva are frequent concomitants. Bell crown teeth are more frequently affected, though the opposite types are not immune. The rounding away toward the gingival of the labial and buccal surfaces of bell crown teeth presents an area in the gingival third which is less readily cleansed by the action of the lips and cheeks, with consequent increased tendency to the accumulation of food here. Also, as previously mentioned, there is a possibility that acidity of the secretion from the gingival crevice, resulting from inflammation of the marginal gingiva may be concerned in the characteristic susceptibility and increased liability to caries. As soon as hypersensitiveness of the surface and tenderness of the gum arise, the patient is more likely to avoid the area with the brush, which still further increases the likelihood of cavity formation. These conditions, together with the tendency of the cavity to extend under the marginal gingiva increase the difficulty of applying the rubber dam. The use of the Hatch or Ivory cervical clamp is in the majority of cases necessary, since dryness is essential and forcing away of the gum from the field of operation is necessary. Where the cavity is extensive and the gum has hypertrophied and grown into it, it will occasionally be necessary to roughly prepare the cavity and force the overhanging gum tissue away by means of base-plate guttapercha packed into it.

Gingival third cavities are likely to occur in groups, affecting tooth after tooth in some particular part of the mouth, as in the incisors, bicuspids or molars. However, they are the least frequent of occurrence of all five types of cavities.

Outline Form.—The gingival margin should be carried under the marginal gingiva, the mesial and distal margins to the axial line angles and the incisal or occlusal margin down to self-cleansing areas. The extension of the gingival margin into the gingival crevice will tend to protect it from recurrence of decay and the carrying of the mesial and distal margins to the angles bordering the surface will place them in relatively immune areas. The amount of extension of the incisal margin on anterior teeth or of the occlusal margin on posterior teeth will depend on the convexity of the surface. On flat surfaces, not much extension will be necessary, but on bell crown teeth this margin should be carried well down to an area where the cleansing effect of the food bolus, as it passes over it in mastication, may be utilized and where the action of the brush is readily brought into play. In many instances, an incisal or occlusal margin following a straight line across the affected surface, rather than a curved line with its convexity pointing gingivally, is better. On thick neck teeth with fairly flat surfaces, a cavity of a crescent or half moon shape with rounded angles may be utilized.

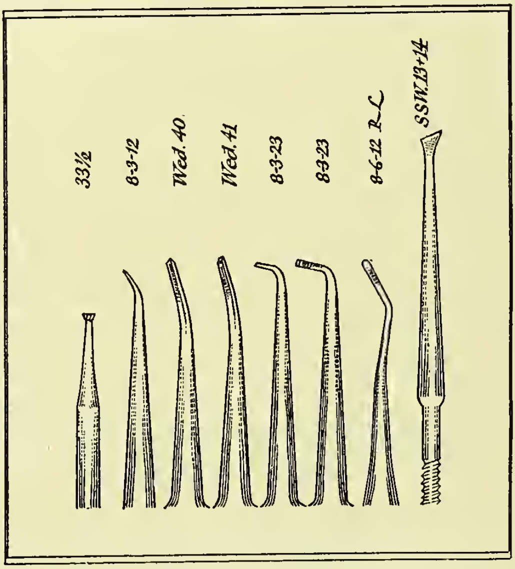

FIG. 442.—Instrument selection for preparation of Class V cavities.

The rubber cloth should be applied at once and the surface dried, in order to determine the depth and extent of the decay. The hypersensitiveness of the tissues will demand extreme care, tact, and encouragement of the patient. All instruments should be at hand and extremely sharp. Obtundents applied locally are not often efficaceous, although they may be utilized for their psychologic effect on the patient. The Hartman obtundent, mentioned in the chapter on Hypersensitive Dentin may be useful. If the cavity is extensive, any unsupported enamel margins should be removed with hoe 8-3-12, or Wedelstaedt chisels 40 and 41, after which the softened dentin should be removed at once with one or two sharp, decisive strokes of spoon excavators 8-6-12, right or left. Figs. 443, 444 and 445. After the removal of the superficial layers of affected tissue in either extensive or small cavities, much of the sensitivity will disappear. In small cavities, the enamel should first be undermined with inverted cone bur 33½, when it may then be chipped away with hoe 8-3-12 and Wedelstaedt's chisels 40 and 41. The hoe will be useful on mesial and distal margins on molars and bicuspids, while the chisels, used with a planing motion will dispose of the enamel on the gingival and occlusal margins. If further extensions are necessary, first remove the underlying dentin with bur 33½ and continue chipping the enamel with the hoe 8-3-12 or planing it away with Wedelstaedt's chisels 40 and 41 until the necessary extensions are made. The same procedures are applicable to similar cavities on anterior teeth.

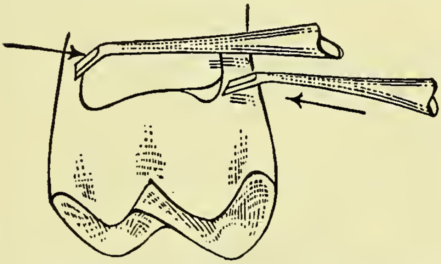

FIG. 443.—Preparation of the outline form in Class V cavity, removing enamel with a hoe, 8-3-12.

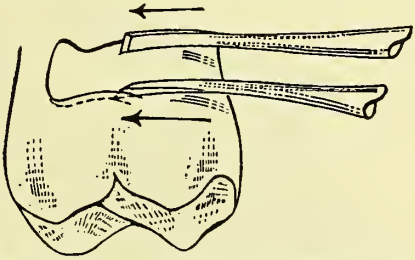

FIG. 444.—Removing enamel with Wedelstaedt chisels No. 40 and 41.

Resistance and Retention Form.—The cavity should now be given the regulation box or mortise shape, with parallel lateral walls placed at a right angle to the axial wall. The axial wall should not be flat but should follow the curvature of the underlying pulp chamber. The amount of cutting into the dentin should not be deep unless the penetration of caries demands it. Just sufficient depth to provide anchorage for the filling should be all that is necessary. The average thickness of the enamel and dentin overlying the pulp on labial and buccal walls is 2.6 millimeters on incisors, 2.9 millimeters on cuspids and 3 millimeters on posterior teeth. The minimum thickness of these surfaces is 2 millimeters on incisors, 2.6 millimeters on cuspids and 2.5 millimeters on bicuspids and molars.

Since the filling will not be subjected to the force of mastication, no special resistance form is required. The box shape to the cavity is prepared with least pain and most conveniently with hand cutting instruments. On molars, hoe and hatchet 8-3-23, freshly sharpened on the edge and sides of the blades, may be used to scrape the axial wall to proper shape, to parallel all four lateral walls and to sharpen the line angles uniting the axial with the lateral walls. Fig. 446. The hatchet 8-3-23 will be useful to prepare the distal and sometimes the mesial wall, cutting with the side of the blade, while the gingival, occlusal and most of the axial wall will be cut to form with the hoe 8-3-23. On bicuspids and the anterior teeth, the hoe 8-3-12 will conveniently and expeditiously accomplish all of this work, without the use of the hatchet. If additional retention form is deemed necessary, two opposing lateral walls may be dovetailed or slightly undercut with the same instruments. Fig. 447.

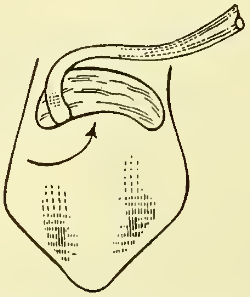

Fig. 445.—Removing the decay with spoon excavator No. 8-6-12.

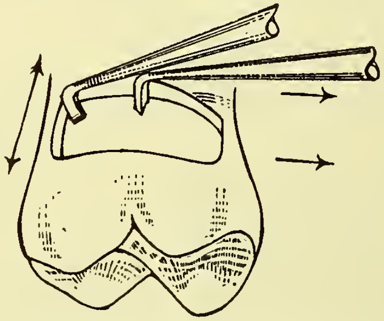

Fig. 446.—Preparing resistance and retention form in a Class V cavity in a molar with hoe and hatchet No. 8-3-23.

Convenience Form.—For convenience in starting gold, the disto-gingivo-axial and the disto-occluso-axial (disto-inciso-axial in anteriors) point angles may be slightly deepened with inverted cone bur 33½. The bur should not be sunk into the axial wall, but the cutting should be more at the expense of the distal and gingival, or occlusal and incisal walls as the case may be. After deepening the point angles, the bur may be drawn forward slightly along the gingivo-axial and occluso-axial line angles. In anterior teeth, the latter line angle will be called the inciso-axial line angle. Fig. 448.

Removal of Remaining Decay.—The cavity should now be inspected for traces of remaining decay which, if found, should be removed with the hoes and hatchets previously used or with spoons 8-6-12 right and left.

Preparation of the Enamel Wall.—The enamel wall should now be thoroughly planed, smoothed and bevelled outward, working along the length of the margin with S.S.W. hard bits 13 and 14 or with bin-angle chisel 15-8-6. The gingival enamel wall should be bevelled full width, 6 to 10 centigrades, to follow the direction of the enamel rods. The mesial, distal and occlusal (or labial) margins should also be slightly bevelled with the same instruments, following which the toilet of the cavity should be made. Fig. 449.

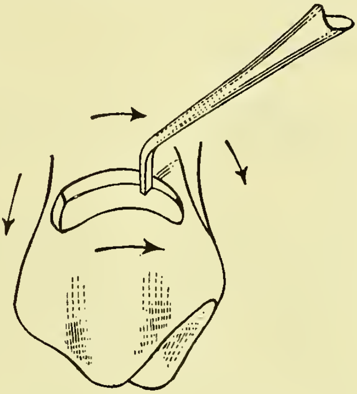

FIG. 447.—Use of hoe 8-3-12 for obtaining resistance and retention form in a Class V cavity in a bicuspid tooth.

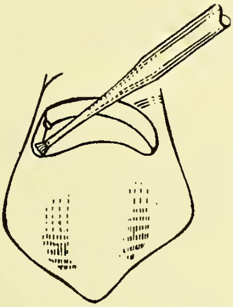

FIG. 448.—Preparing convenience form with a 33½ inverted cone bur.

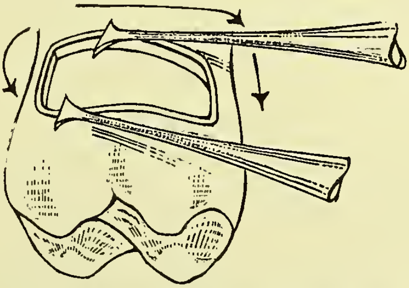

FIG. 449.—Finishing the enamel margins with hard bits Nos. 12 and 13.

GINGIVAL THIRD CAVITIES WITH RECEDED GUMS

In cases of receded gums, labial or buccal cavities will sometimes be found extending beyond the gingival line into the cementum of the root. When found in the aged, the condition has been designated by Black as "Senile Decay." The pathology and method of handling are the same as described for ordinary Class V cavities, the only difference being the tendency to recurrence of decay, owing to the fact that the gingival and sometimes other margins have to be located in the cementum rather than in enamel. No further description of this type of cavity is necessary.

CHAPTER XIV

RESTORATION OF THE CONTACT POINT AND SEPARATION OF THE TEETH

A study of the "human form divine" reveals the fact that occasionally mother nature designs or gradually evolves faultless models; but, through inheritance or environment, acting over long periods of time, these ideal forms often become marred and less perfect types are produced. In no case may this be better illustrated than in a study of interproximal spaces, embrasures and contact points. Fig. 450.

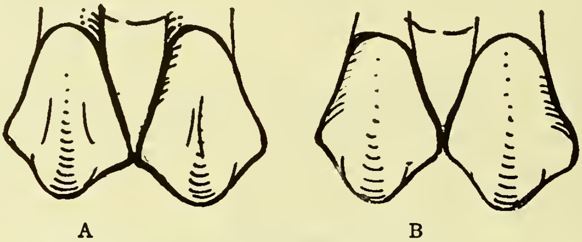

FIG. 450.—Types of interproximal contact. A, contacts too close to occlusal surface. B, correctly placed contacts.

IDEAL FORMS

In pursuing this aspect of the subject, we find that the ideal conditions at which nature aims, but frequently fails to produce, in these localities, are the following:

First.—A perfect V-shaped interproximal space between two adjoining teeth; this space gradually widening out to the labial or buccal and lingual surfaces, to form the embrasures.

Second.—Well rounded interproximal embrasures, those on the lingual aspect being more pronounced in the posterior part of the mouth, while those on the labial side are more marked on the anterior teeth.

Third.—The base of the triangular-shaped interproximal space is at the alveolar border, while the apex is at the points of contact.

Fourth.—These so-called "spaces" are, under normal conditions, not really spaces at all, but are occupied by healthy gingival tissues.

Fifth.—The ideal form of contact between two anterior proximating teeth is similar to that produced by placing two marbles together—

the "marble contact point." See Fig. 451. This contact point on posteriors is more nearly a contact surface, and should measure on an average 1½ to 2 millimeters bucco-lingually and occluso-gingivally, being slightly wider bucco-lingually. The contact point is situated nearer the lingual embrasure on anteriors and to the buccal side on posteriors.

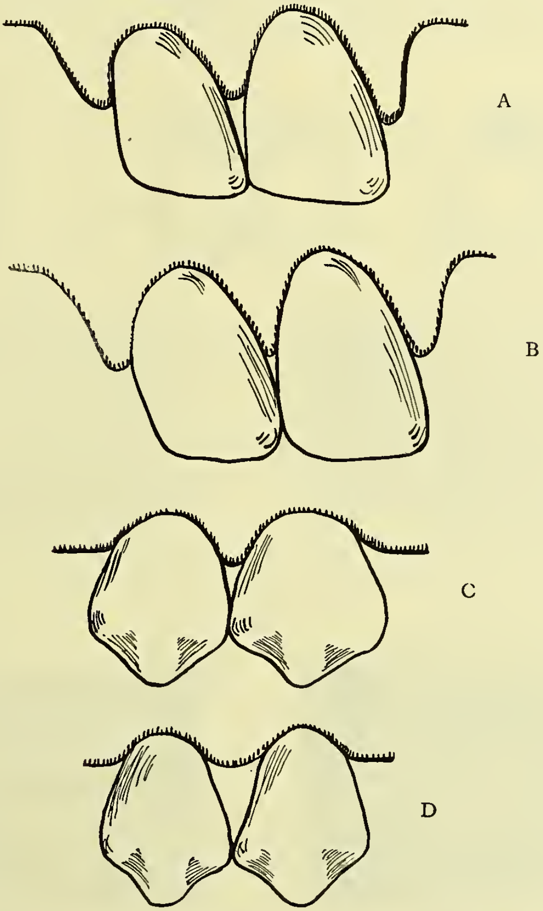

FIG. 451.—Types of interproximal contact. A, good contacts, often seen on natural teeth, but too close to incisal angle. B, fair contacts, a little too broad, with interproximal space too narrow. C, fair contacts, a little broad. D, good contacts, but too close to occlusal surfaces.

Sixth.—The average measurement of the normal arch in early life from the distal surface of the third molar on one side to that of the other side, through the contact points, is one hundred and twenty-seven millimeters, (about five inches); while the average total measurement of the mesio-distal diameter of the teeth at the gingival line, is eighty-nine millimeters (about three and five-tenths inches); leaving the average total measurement of the bases of the interproximal spaces as thirty-eight millimeters (about one and five-tenths inches).[1]

FAULTY FORMS AND THEIR RESULTS

These ideal conditions, as previously mentioned, are not always found and, even if originally present, frequently are marred by the stresses incident to time, wear, local irritants, constitutional disturbances and imperfectly-performed dental operations. A class of contact, frequently observed, is broad and flat and found in connection with so-called "thick-neck" teeth. This is far from the ideal form. Fig. 452 A similar variety is often produced with age, through interproximal wear, as a result of the sliding of the contact points against each other, and the formation of broad facets in these localities. Another faulty form is often seen in which the teeth are not in contact, a slightly open space being present, in which food tends to pack. Figs. 453 to 456. At a period of about forty years of age, the average length of the arch is usually diminished one centimeter, or about one-third of an inch, through the drifting forward of the teeth, as a result of interproximal wear and caries. From

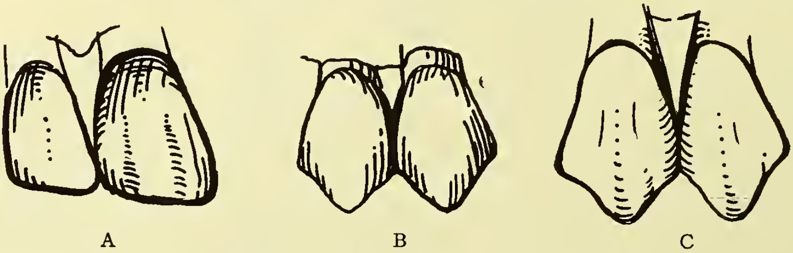

FIG. 452.—Types of interproximal contact. A, good contact. B, very flat contact. C, better contact than B, but still too flat.

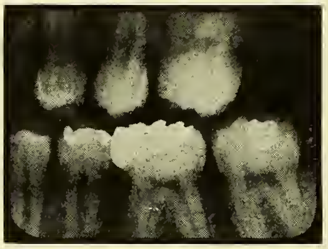

FIG. 453.—Amalgam filling poorly contoured in lower first molar. Open contacts, upper and lower teeth.

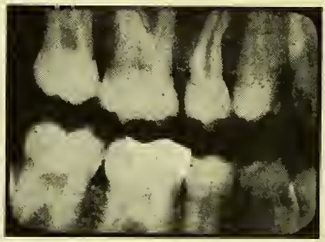

FIG. 454.—Poor contour and faulty contact on filling from lack of separation. Open contact above.

these two causes, as well as those incident to age, imperfectly-restored proximal fillings, local mechanical irritants and constitutional disorders producing lowered vitality of the tissues, the interdentinal papilla which in the early periods of life is full and resistant, frequently is absorbed and affected with various pathological disturbances.

A study of the morbid anatomy of the affected tissues is exceedingly interesting. Very briefly, the histopathology of these conditions may be described as follows, viz.:

First.—Properly-designed contact points protect the highly-sensitized and delicately-formed gum septum against the too-strenous buffeting of food masses.

Second.—Imperfect formation, destruction or improper restoration of these contacts facilitates impactions of irritating food substances into the interproximal space and leads to too vigorous use of tooth picks and similar implements for their removal.

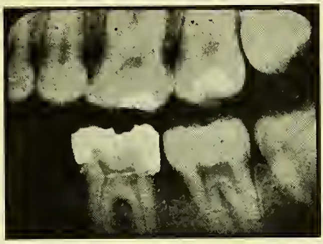

FIG. 455.—Open flat contact on filling and overhang at gingival margin.

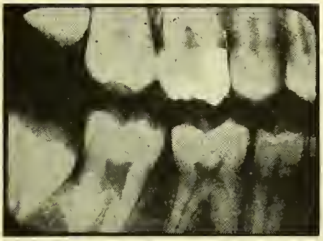

FIG. 456.—Flat contour on filling from improper separation. Artefacts at gingival, simulating caries.

Third.—This results in: (*a*) arterial hyperemia; (*b*) venous hyperemia; (*c*) inflammation, either acute or chronic, of the superficial tissues, accompanied by pain, deepening of the gingival color, bleeding and hypertrophy in the acute cases, with subsequent absorption in the chronic cases.

Fourth.—An extension of these processes occurs in the interstitial submucous tissues, periosteum, pericementum and bone, the vasomotor nerves of the part being first stimulated, then over-stimulated and finally depressed in activity.

Fifth.—Even if infection does not occur, degeneration and absorption of the supporting tissues results in the formation of a pocket, which further facilitates accumulations of food.

Sixth.—Infection in the majority of cases results in suppuration and pus formation, with destruction of the soft tissues, and a rarefying osteitis and caries of subjacent bone.

Seventh.—Ultimate loss of the affected teeth and an extension of the pyorrheal condition to those adjoining is the result.

Eighth.—In the majority of cases, early caries of the proximal surfaces of the affected teeth, with cavity formation, occurs, as a result of the fermentation of the impacted food masses, long before many of the previously mentioned disturbances arise.

THE REMEDY

The fact already has been accentuated that nature frequently fails to construct ideal contact points. The dentist always should endeavor to produce them and thus improve on nature. When interproximal wear exists, the patient often will complain of discomfort in these localities. In cases of this character, the teeth should be separated, and even if no evidences of decay are present, cavities should be prepared and normal contact points built over-full in order that the condition may be relieved. In cases of large proximal cavities, the teeth have frequently drifted together. They should be lifted apart sufficiently to restore their mesio-distal diameter, and normal contacts built. Recalling the fact, previously stated in regard to the shortening of the total length of the arch with age, resulting in a lessening of the area and power of the masticating machine and a narrowing of the interproximal spaces, an effort always should be made to restore normal conditions. This must be accomplished by separation and the accentuation of contacts in every instance where operations are to be performed on proximal surfaces of teeth in the mouths of patients of middle age and beyond. In Fig. 457 is seen the method of measuring the width of the contact points. For the following reasons, then, the maintenance of normal V-shaped interproximal spaces is necessary:

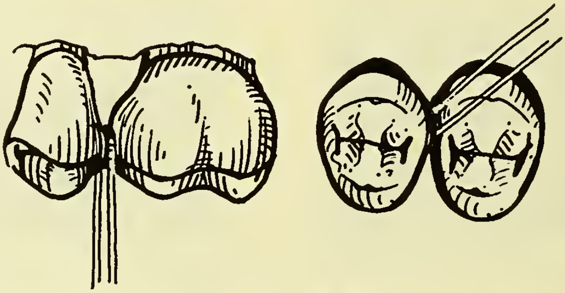

FIG. 457.—Testing with floss silk the bucco-lingual width of the contacts between a bicuspid and a molar and the occluso-gingival width of the contacts between two bicuspids.

First.—To prevent impaction of food.

Second.—For conservation of healthy gum tissue.

Third.—To enable patients to more readily accomplish the cleansing operation.

Fourth.—To help insure permanence of proximal fillings.

Fifth.—To improve esthetic appearance, especially on anterior teeth.

Separation of the teeth is not only advisable, but absolutely necessary in every instance, if the best results are to be obtained. A study of the accompanying illustrations (Figs. 450 to 456) will indicate the undesirable and the ideal form of contact point and interproximal space to be reproduced in operating in these localities.

SEPARATION OF THE TEETH

Separation is often necessary:

First.—For proper examination of interproximal spaces.

Second.—For preparation of proximal cavities.

Third.—For proper restoration of anatomical proximal contours and normal contact points in fillings.

Fourth.—For preservation of healthy interproximal gum tissue.

For accomplishing separation of the teeth two general methods are in use, viz.:

First.—Slow or previous separation, and

Second.—Rapid or immediate separation.

In the first method, the teeth are slowly and gradually forced apart through the expansive properties of certain materials, previously inserted between them; while the second method admits of their immediate separation through the use of steel appliances specially designed for the purpose. Both have their advocates, advantages, dangers and disadvantages.

The chief disadvantage in slow or previous separation is the time consumed, it often requiring several days and repeated applications of the separating material. Its advantages are

1. Comparative absence of soreness of the teeth.
2. Lessening of danger of tearing the fibers of the pericementum.
3. Ability to temporarily force away, with guttapercha, (one of the materials used), swollen gum tissue from the gingival margins of cavities.

The advantages and disadvantages of rapid separation may be mentioned as follows:

Advantages.

1. Quickness.

2. Ability to steady or prevent movements of the teeth during the filling operation.

Disadvantages.

1. Danger of rupture of the fibers of the pericementum and permanent loosening of the teeth, through injudicious use of force.

2. Pain of too rapid separation.

Of the two methods, rapid separation is most advantageous and frequently used, although this is not always advisable, or possible. The two methods are frequently combined with good results.

PREVIOUS OR SLOW SEPARATION

The materials used in previous separation are guttapercha (baseplate or any variety of permanent guttapercha); wood (orange-wood or hickory), trimmed into a wedge; rubber dam or orthodontia bands (a small section forced between the contact points); and French twist silk ligature.

The method of use of these materials is herewith described. The selection will depend on the conditions present in each case.

Guttapercha.—The material may be used in case of a proximal cavity on a bicuspid or molar, or of adjoining proximal cavities in the same space on posterior teeth. Pack the cavity over-full, avoiding the danger of too much pressure on the gum, and instruct the patient to use the tooth vigorously. Leave it in position for several days or weeks and renew, if necessary, until separation is accomplished.

Wood.—Trim an orange-wood stick into a wedge of suitable size and shape, force carefully and lightly into position and cut off the excess with wedge cutting forceps; or cut a deep notch in the wood where it is desired to remove the excess, and after insertion of the wedge break it off at the location of the notch. Absorption of moisture will caüse expansion of the fibres of the wood and result in separation. Wooden wedges also are valuable, when used more forcibly, to produce immediate separation in cases where the matrix is in position. Also, they assist here to hold the matrix band in close contact with the tooth at the gingival margins of cavities.

Rubber.—Its use is undesirable in the majority of cases, on account of the soreness produced, incident to its rapid expansion. If used for special reasons, stretch and force the rubber into position between the contact points, avoiding pressure on the gingiva. Remove the excess with a pair of scissors and allow it to remain in position from twelve to twenty-four hours. If extreme soreness is produced, maintain, by means of guttapercha, the separation gained, until all soreness subsides. Rubber separating strips should be avoided for this purpose, using preferably a small strip of rubber dam or rubber orthodontia band.

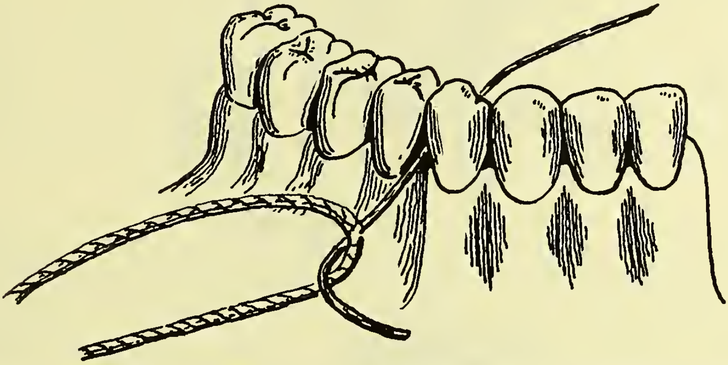

Fig. 458.—Application of French twist silk ligature between the teeth to produce slow separation. First step.

French Twist Silk Ligature.—This is a valuable method for producing slow separations where cavities are small or absent. It may be used on either anterior or posterior teeth. The ligature is supplied in fine, medium, or coarse sizes and is also often used by orthodontists, because it contracts when moist. The technic for its introduction is as follows: Pass a piece of waxed dental floss past the contacts of the teeth to be separated and into a loop of the silk ligature. See Fig. 458. Then carry the other end of the dental floss into the interproximal space and draw the silk ligature into position from the buccal or labial embrasure as illustrated in Figs. 459 and 460, when the floss is withdrawn. One end of the silk ligature is next passed over the occlusal surfaces of the teeth

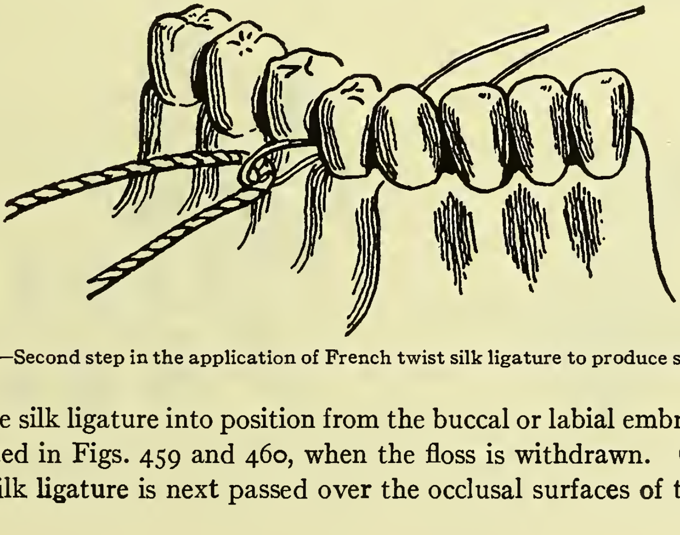

Fig. 459.—Second step in the application of French twist silk ligature to produce separation.

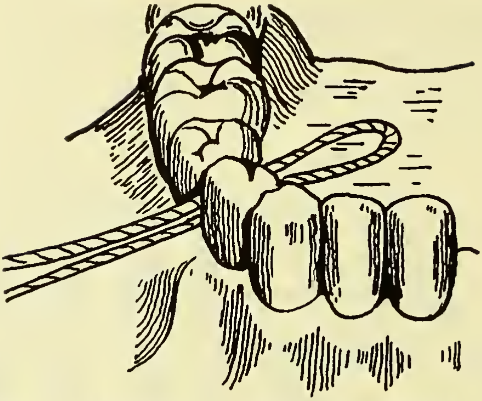

FIG. 460.—Third step in the application of French twist silk ligature. Ligature in position.

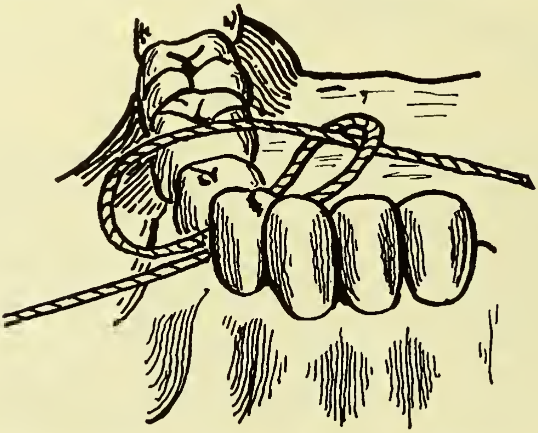

FIG. 461.—Fourth step in the use of French twist silk. Tying the first half of the knot.

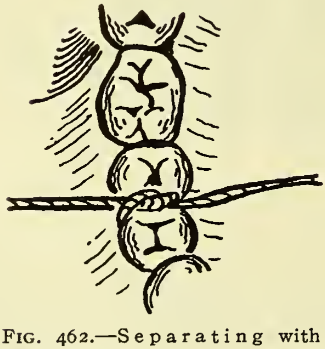

FIG. 462.—Separating with twist silk ligature. First half of the knot tied.

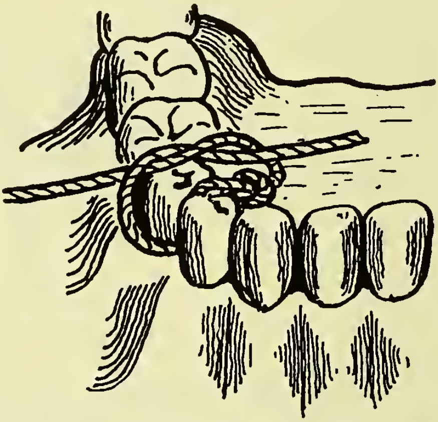

FIG. 463.—Completing the knot in the use of French twist silk ligature for separation.*

* Drawings by Dr. T. E. Rochford.

and through the loop on the lingual side, as seen in Fig. 461. The two ends of the ligature are now brought together, traction is made on them and a double knot is tied, after which the surplus ligature is cut off, the knot resting between the teeth, occlusal to the contact point. See Figs. 462 and 463. In cases with very close bite, it will be better to make the knot so that it will rest in the embrasure rather than on the occlusal surfaces. The modifications necessary for application to anterior teeth are obvious. Contraction of the silk in the presence of moisture tightens the loop and usually creates separation of the teeth in a few hours.

RAPID OR IMMEDIATE SEPARATION

This is the most valuable and frequently used method. Separation usually is accomplished in a few minutes by the use of specially constructed steel separators, which act on either the wedge, or traction principle. The first of these were invented by Doctor O. A. Jarvis in 1874. In their use they should be very carefully adapted, to avoid injury to the gum septum and the tooth at the dentino-cemental junction. The force should be very slowly and gradually applied, else pain is produced and the pericemental fibres may be unduly stretched or torn. If this occurs, permanent loosening of the teeth and pre-disposition to pericementoclasia will result. Also, injury to the tooth at the cervix, however minute, may be the starting point for dental caries. Carefully used, the rapid separator is a valuable instrument; in the hands of the inexperienced and thoughtless operator, it is a very dangerous appliance.

Occasionally the teeth will be found very firmly implanted in dense bone and difficult to move. In cases of this nature, the force should be applied very slowly, waiting a few moments between each turn of the screw, or tightening device, and encouraging nervous patients as the separation progresses. Occasionally it may be better to use a combnation of the slow and rapid methods in this type of cases, starting with the slow method until separation is partially accomplished and completing the operation with the rapid separator. Or, *vice versa,* after separation with the rapid separator has progressed to the point where it is felt that the force necessary to complete the procedure may be dangerous, one of the slow separating materials may be placed in position until the next visit, when, if at that time, separation is still inadequate, it may be finally completed with the rapid separator. Fortunately, there are few cases of this nature, the rapid separator, carefully applied and skillfully and tactfully handled, producing the desired result without particular difficulty.

The mechanical or rapid separator is a valuable appliance for the following purposes, viz.:

First.—For examination of interproximal spaces.

Second.—Preparatory to slow separation.

Third.—To maintain space gained by previous separation.

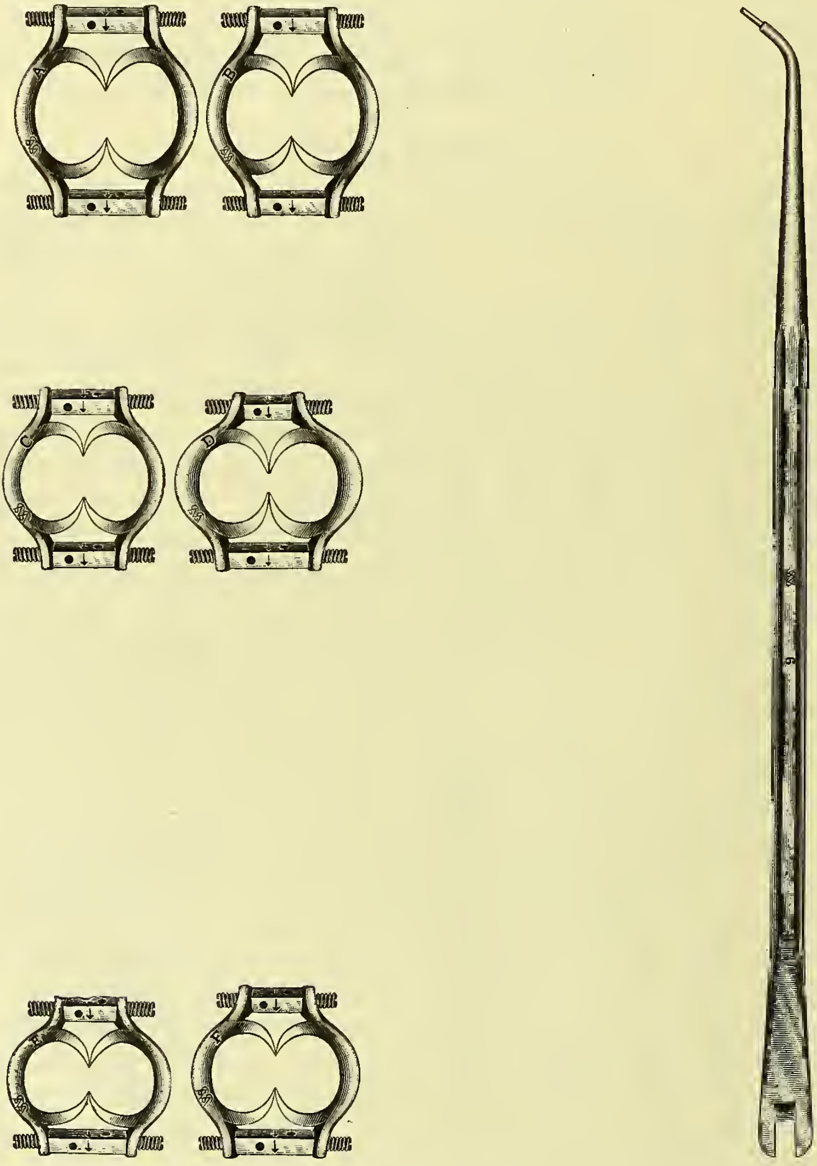

Fig. 464.—Set of six Perry separators and wrench. Traction principle.

Fourth.—For preparation of cavities.

Fifth.—For insertion and polishing of fillings and inlays.

Sixth.—For removal of foreign bodies, such as berry seeds, fragments of tooth picks or bone sequestra.

The set of six separators designed by Doctor Safford G. Perry in 1881 are by far the most valuable appliances yet devised for producing rapid separation of the teeth. The set offers a variety of forms which make it available for use in any location. They act on the traction principle, drawing, rather than wedging the teeth apart. See Fig. 464.

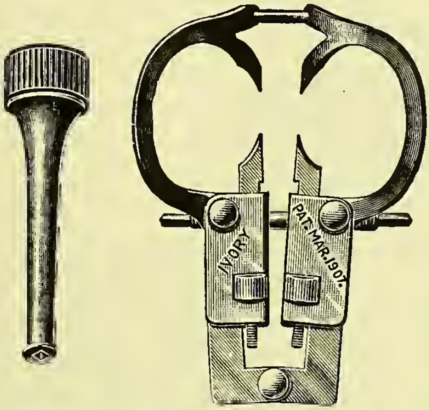

Fig. 465.—Ivory universal separator. Traction principle.

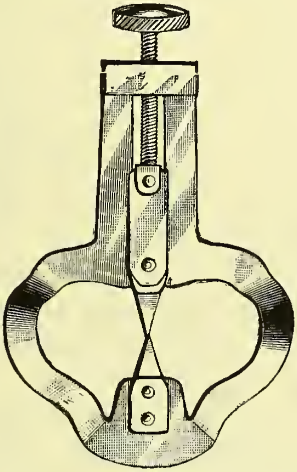

Fig. 466.—Double bow separator. Wedge principle.

In adjusting them to position, care should be taken to tighten the set screws on buccal and lingual sides equally as separation progresses, with the wrench provided for the purpose. If one bar is turned much more than the other, it causes the screws to bind and work hard. They should generally be placed with the short bar to the lingual side and the claws fully closed. One bar should be given two or three quarter turns and then the other, gradually progressing in this manner to keep the instrument steady and prevent binding of the screws. After the separator is tightened to position so that it is held in place, if the bows do not rest securely on the incisal edges or occlusal surfaces of the teeth, they should be propped up with softened modeling compound or guttapercha placed under them. This is to prevent the claws from sliding too far gingivally and wounding the soft tissues, and also to steady the separator against undue movement during later manipulation incident to preparing the cavity or inserting the filling. This should be done before separation is begun, else the claws will be likely to slide gingivally during separation and prevent the later insertion of the props under the bows. These separators exert a continuous spring force even after tightening, which is likely to cause undue separation, unless this is borne in mind. For this reason, it is important to proceed slowly, with resting periods between the tightening of the bars, and not to complete the separation at once, else too much separation is likely to be gained before the operation is completed. It will be better with single rooted teeth to tighten the bars gently at first, begin the operation and then give the bars a quarter turn or two at intervals as the operation proceeds, to avoid too much separation.

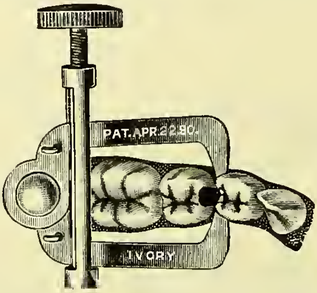

FIG. 467.—Elliot separator. Wedge principle.

The Ivory Universal, Double Bow and the Elliot separators (Figs. 465, 466 and 467) also are used by many. The former is a traction instrument, while the two latter act on the wedge principle. Neither of these separators are very effective on posterior teeth, as the lips and cheeks interfere with their ready adaptation.

Bibliography

1. Black, G. V.: "Dental Anatomy," 4th ed., p. 136.

McGehee, W. H. O.: Restoration of the contact point, American Dentist, May 1916.

CHAPTER XV

USE OF THE MATRIX IN FILLING TEETH

The word "Matrix" is derived from the Latin *mater*, mother. The definition, as given by the Standard Dictionary, "That which contains and gives form to anything," is all-inclusive and descriptive of various forms of matrix, as used or seen in mechanics, the arts and the sciences, including dentistry. A dental matrix may be defined as a properly-shaped piece of metal or other material used to support and give form to the filling during its introduction and hardening.

The use of the matrix is essential to the proper contour of proximal, proximo-incisal or proximo-occlusal fillings of a plastic nature. Another form of matrix also is used for a different purpose in porcelain work and is described in that chapter. There are many forms of matrix bands and retainers supplied by the manufacturer, but the dentist often may adapt matrices of his own construction with far better results.

Matrix bands should possess the following essential qualities:

First.—Easy adaptability and fixedness to the teeth.

Second.—Provision for proper contouring.

Third.—Resistance against the pressure necessary for insertion of the filling.

Fourth.—Capability of easy introduction and removal.

The first successful matrices were introduced into dentistry by Doctor Louis Jack in 1871. The dental matrix is used for the following purposes, viz.:

First.—To act as a temporary wall of resistance during introduction of the filling.

Second.—To give shape to the restoration.

Third.—To maintain the form of the filling during hardening or setting.

Fourth.—To assist in holding back the gum and rubber dam during introduction of the filling.

Matrix bands are made of steel, phosphor-bronze, copper and celluloid. The celluloid matrix consists of a thin strip of celluloid held in position during the hardening of silicate and other forms of cements. There are many well-known forms of Patent Matrices, consisting of the band

and holder. Prominent among these may be mentioned the Ivory matrices. Figs. 468 and 469. The bands of the patented matrices are usually of steel or phosphor-bronze. Usually they do not produce the satisfactory results obtained by matrices of thin copper specially constructed for individual cases by the dentist. Herewith are describe several forms of matrices for use in special cases.

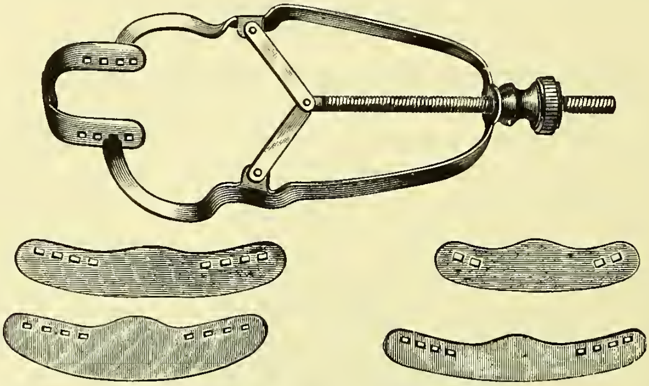

FIG. 468.—Ivory matrix holder and bands.

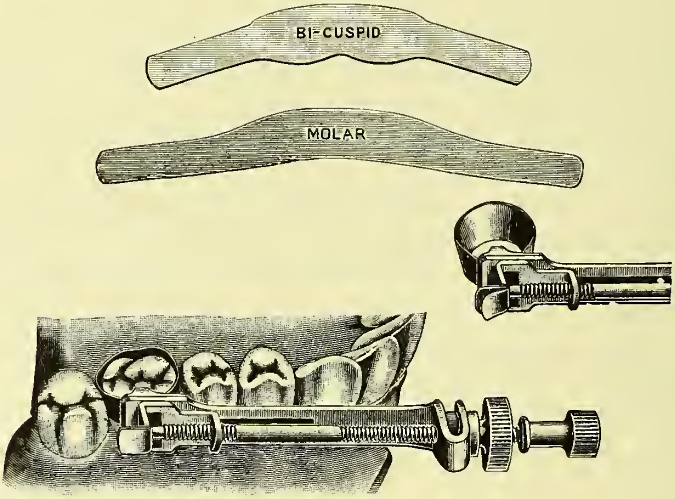

FIG. 469.—Ivory matrix holder and bands.

The Soldered Band.—This is made by taking a measurement of the neck of the tooth and soldering a band of metal to fit. Fig. 470. Thirty-six gauge copper is suitable for this purpose, or a ready made seamless copper band of proper size may be selected. In either case the band should be trimmed and neatly fitted at the gingival margin to avoid undue impingement on the gums. Also, it must be trimmed short of occlusion, since it must be allowed to remain in position, completely encircling the tooth, after the introduction of the amalgam, until the next appointment. It should be wedged into position by means of small wooden wedges on mesial and distal sides, and should be contoured closely against the proximating teeth before insertion of the filling. The wedges will produce the necessary separation and the contouring of the band will give the filling proper form. The wedges may be removed after the carving of the occlusal surface of the filling and before dismissing the patient. At the next visit, the band may be split on buccal and lingual sides with a sharp knife and carefully removed, when the final finish is given the restoration. This form of matrix is valuable for badly broken down molars requiring extensive restoration.

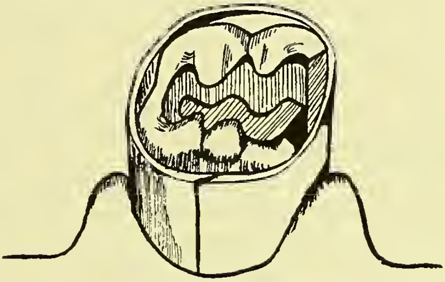

Fig. 470.—Soldered band matrix.*

The Tied Band.—In case, for any reason, it is not convenient to construct the soldered band as described, a band to encircle the tooth may be made after one of the following methods. However, the tied band usually is not as efficient. Clamp with pliers a piece of copper band metal around the tooth, pinching the ends tightly together. Remove and tie at the point of junction with binding wire, after which bend back the projecting ends, one to the mesial, the other to the distal, and place in position on the tooth. The band should first be trimmed to proper width and of sufficient length to allow for grasping by flat nose pliers while ligating, and for bending the ends mesially and distally on the buccal side.

Another Tied Band.—Take a measurement of the neck of the tooth and cut a piece of metal of the proper length and width. Punch a hole near either end. Pass a ligature through one hole, then along the length of the band, and back through the other hole. Place the band in position with the ligature on the outside of the band and tie to place on the buccal side, wrapping the ligature around the tooth several times, if necessary. The band should be slightly shorter than the circumference of the tooth, to prevent overlapping of the ends in tying to place.

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*The drawings in this chapter were made by Drs. J. D. Lombardi and G. S. Corriero.

The Wedged Matrix.—Cut a piece of band metal of proper shape to supply the missing wall and to extend slightly on the buccal and lingual surfaces of the tooth beyond the buccal and lingual margins of the cavity. Wedge to place in the interproximal space with orangewood, to gain separation. This matrix may occasionally be used for very simple proximal operations in the mouths of children, where cement or guttapercha is the material of choice.

The Black Matrices.—Doctor G. V. Black presented to the profession several methods of preparing matrices for use in individual cases. Two of these are illustrated in Figs. 471 and 472. The first is the simplest form and that which he recommended for the majority of the small and medium size cavities. In these cases, it will often be sufficient to cut the band so that it will extend only slightly over the buccal and lingual surfaces of the tooth. The tendency with all tied bands is for the ligature to slip off of the band and slide gingivally. This is prevented in the Black bands by turning up the corners of the gingival ends in the first form illustrated, while in the second form, an additional hold on the ligature is secured by cutting two slits on either side and turning them up over the ligature, thus, holding it in this locality, as well as at the end of the band. The second form is for badly decayed teeth. In this form, an extension is cut in the middle of the gingival edge to cover the gingival margin of deep seated cavities.

All matrix bands should be trimmed smooth and corners rounded, to prevent the cutting of ligatures and wounding of soft tissues. The ligature should be securely tied with a surgeon's knot on the buccal side, first wrapping it several times around the tooth if necessary. Fig. 473. Also, proper provision should be made to prevent the ligature from slipping out of position. Then a wooden wedge should be carefully adjusted, to produce and maintain proper separation and to hold the band tightly over the gingival margin of the filling. This should secure proper "knuckling" of the contact points and prevent forcing filling material between the band and the tooth at the gingival margin. If amalgam is allowed to enter here, it will be very difficult to remove later.

The matrix may be used in conjunction with the Perry Separator. After the separator is placed lightly in position, the matrix is slipped between the teeth and the claws of the separator. The separator is then tightened into position while holding the band in place. Or the band may be first ligated and the separator then placed on the teeth

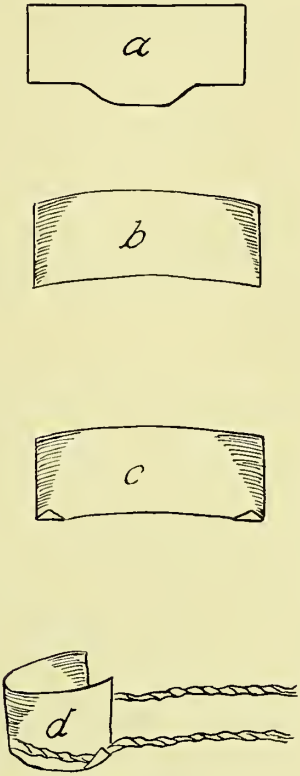


FIG. 471.—Black matrix for simple cases.

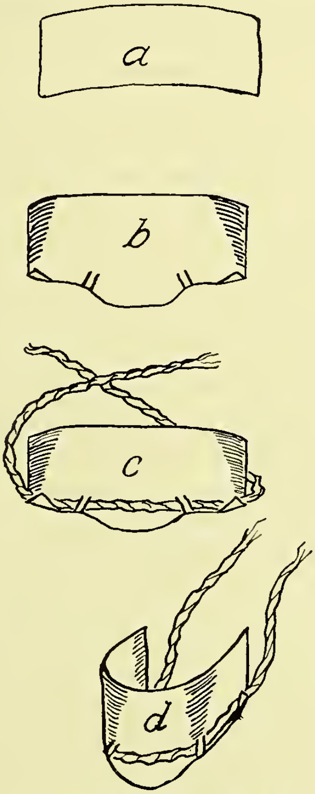


FIG. 472.—Black matrix with gingival extension to cover the gingival wall of deep seated cavities.

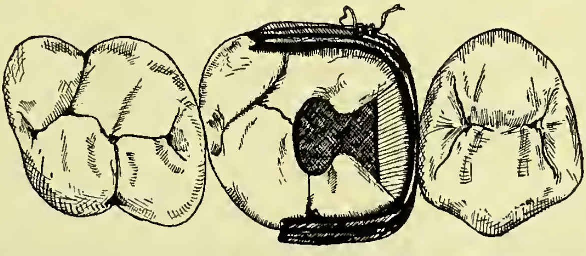


FIG. 473.—Matrix band in position and tied to place. (Dr. Corriero.)

and over the band. After matrix bands are in position, they should always be contoured tightly against the proximating tooth with a suitably shaped burnisher, so that the contact point may be properly restored.

The Crandall Matrices.—Doctor W. G. Crandall introduced a modification of the Black matrices in which a hole is cut in the band at the location of the future contact point. This hole may be made with a number three round bur. A slit is then made in the band with a special pair of scissors, the slit extending occlusally and gingivally from the hole, not quite to the edges of the band, to allow for weakening of the matrix in that locality and ready removal later. A modification of this method is to cut a slit entirely through from the hole to the gingival edge. After insertion of the filling, the band may be easily torn at the slit, the halves being removed, one buccally and the other lingually. The amalgam, during introduction, is packed through the hole and tight against the proximal surface of the adjoining tooth, thus building out a pronounced contact point, which is to be polished later.

A New Matrix Band.—The matrix herewith illustrated (Fig. 474) is an improvement over the other forms mentioned, since it possesses the advantages of easy construction and application, secureness of adaptation and ready removal. It is made of copper band material .002 inch in thickness, with an extension to cover the gingival margin of the cavity. A slit is cut on either side of the extension and the entire gingival edge of the band is then turned up from the slit to the end on either side. The ligature is first placed in position on the band and securely held in place against slipping, by the upturned edges. Band and ligature are then carried to place at the same time, the ligature being wrapped around the tooth and secured with a surgeon's knot on the buccal side, when an orange-wood wedge is carefully fitted into the interproximal space and the band then carefully contoured from the inside with a ball burnisher.

Great care should be exercised in the removal of all forms of matrix bands to prevent flattening of the contact point or marring or dislodging the filling before hardening. Sufficient time should be allowed for beginning crystallization of amalgam before removing the separator, else the teeth are likely to drift together and increase the difficulty of removal of the band and the danger of damage to the restoration.

Matrices are applicable for the manipulation of amalgam, cements, (including silicate) and guttapercha. Some operators use them for gold fillings, starting on the gingival wall with non-cohesive gold, but this method is not recommended by the author. There is always danger of imperfect adaptation of gold to the margins, owing to obscuring of the light and rendering the margins more inaccessible.

Matrices are used on anterior teeth for insertion of oxyphosphate and silicate fillings. For this purpose, a thin strip of celluloid is adapted and, after the filling is inserted held tightly in place until the plastic material hardens. The method of its use is described in its proper place.

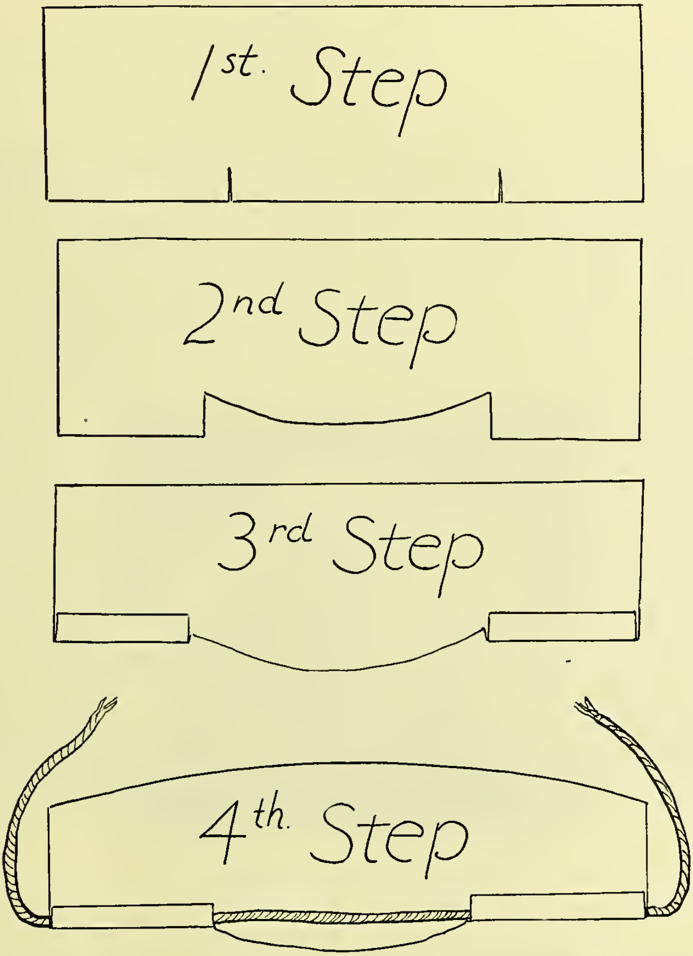


FIG. 474.—Steps in the construction of the new matrix band.

Whenever matrices are used, separation of the teeth is necessary to allow for the space occupied by the matrix band, and for finishing the filling, so that contact points may be restored and "knuckled." The danger of injuring the soft tissues and of producing pain should constantly be borne in mind during the use of matrices.

CHAPTER XVI

RESTORATION OF TOOTH STRUCTURE BY MEANS OF FILLINGS—TOOTH FORM AND OCCLUSION—FUNCTIONS AND CLASSIFICATION—GUTTAPERCHA—CEMENTS

In the previous chapters the proper formation and shaping of cavities for the reception of tooth restorations was described. In this and succeeding chapters, the physical, chemical, and metallurgical properties and the technic of manipulation of the various materials used for restoring tooth structure in Operative Dentistry are considered.

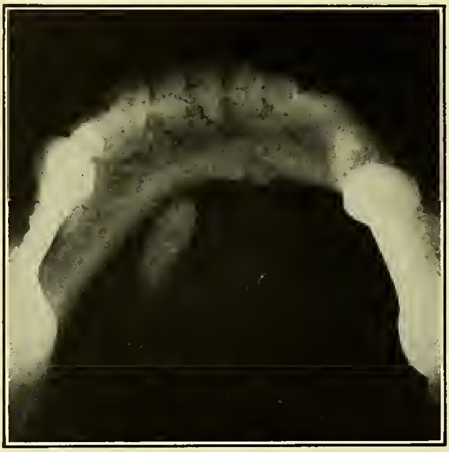


Fig. 475.—Large stone in sub-lingual gland. Mistaken for bicuspid tooth. Also shows four genial tubercles on mandible.

TOOTH FORM AND OCCLUSION

A Tooth.—A specialized organ, of a hard calcareous nature, usually located, though not always, in the mouth or some other part of the alimentary canal, designed for the purpose of assisting in the performing of one or more of the following acts or functions, viz.: prehension, incision, mastication, defense, attack, digestion, speech, and regulation of facial contour. Fig. 475.

A Human Tooth.—A specialized organ, of calco-globulinous nature, situated in the alveolar process of the upper and lower jaws, designed for purposes of mastication, to assist in articulate speech and to regulate facial contour.

An Unerupted Tooth (Human).—A tooth in process of development, but which, although moving toward the surface is still unexposed to view.

An Impacted Tooth (Human).—A tooth whose eruption is interfered with or prevented, with the result that it remains imbedded, and sometimes encapsulated, in the tissues of the structure in which it originated.

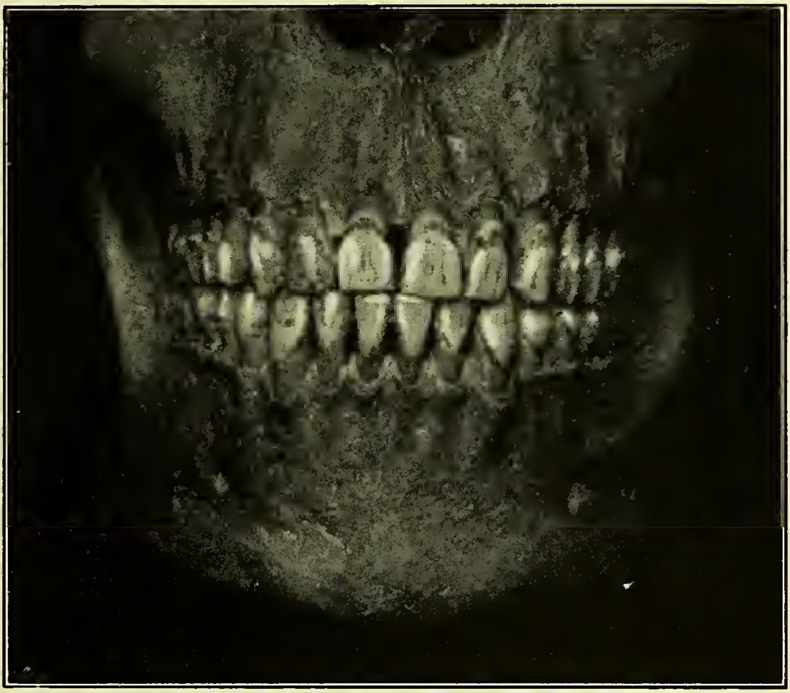


Fig. 476.—Anterior view of maxilla and mandible showing normal occlusion. Skull in the collection of Dr. Milo Hellman.

Before beginning the study of the restoration of tooth structure through the filling operation, the student should have become thoroughly acquainted with the form and structure of the teeth, the laws of occlusion and the functions and mechanism of the masticating machine as a unit. The teeth should not be looked upon as separate organs, but as parts of a machine, designed by nature to perform certain definite and important functions, and whichis activated by nerve-controlled muscles. The teeth can perform no functions by themselves, but are motivated through the action of the physiologic and biologic factors of the mouth. Fig. 476.

The teeth, when acting as parts of a unit are designed for (1) prehension, incision and mastication of food, (2) to assist in articulate speech, (3) to regulate facial contours and (4) to protect the soft tissues of the mouth from injury incident to food impactions. The chief of these functions is mastication of food. If the teeth are not properly related in form and arrangement to the forces which motivate them, the functions of the machine are lowered, its usefulness is diminished and its component parts become more subject to pathologic processes. The various anatomic markings on the teeth are designed to most efficiently accomplish the previously mentioned functions. The cusps, ridges, grooves, contours, and contact points are important adjuncts in the performance of these functions. It is important, then, that a comprehensive knowledge of the purpose, form, location, and relationships of these parts be possessed by the dentist, in order that he may maintain or restore them in his operative procedures. Figs. 477 and 478,

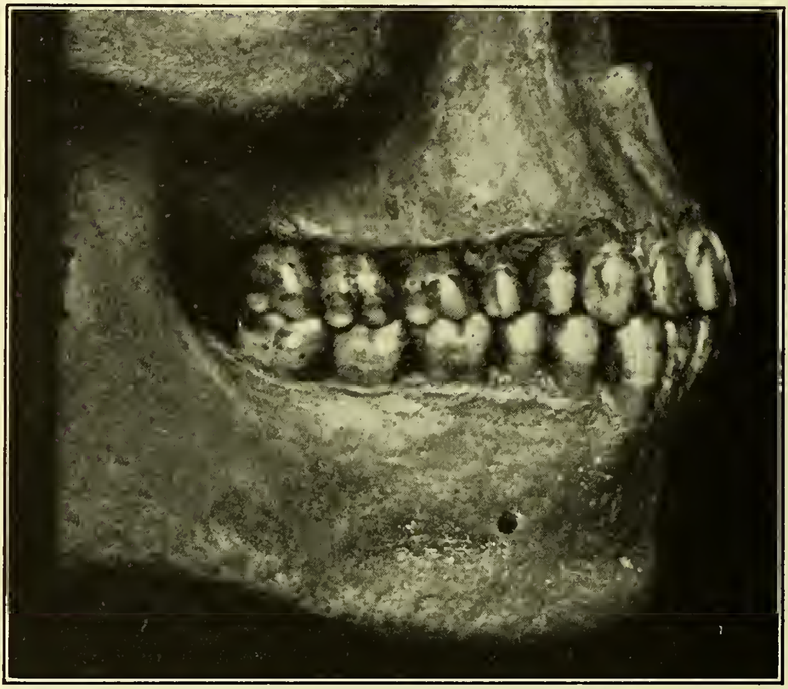


FIG. 477.—Normal centric occlusion of the right side. Very little evidence of the curve of Spee. Skull from the collection of Dr. Milo Hellman.

The arrangement of the teeth in the arch has a definite relationship to the movements of the condyle of the mandible in the glenoid fossa, and this arrangement and relationship provides for proper closure of the teeth in centric occlusion and for the lateral, protrusive, retrusive and hinge movements incident to mastication. The normal overjet of the maxillary teeth satisfies the requirements of the lateral mandibular movements, while the slight protrusion of the maxillary incisors provides for the forward movements incident to prehension. The paths of the various mandibular movements are in the form of arcs, and the teeth of opposing jaws are arranged into opposing arches whose arcs allow for these paths of movements, either vertically, forward and backward, or laterally. Anteriorly, in the region of greatest lateral motion, the incisal edges of the opposing teeth act as the blades of a pair of shears, being designed for prehension and incision. There is a gradual diminution in the size of the buccal cusps from the first bicuspid to the third molar, corresponding to the progressive diminution in size of the arcs formed by mandibular movement. The cusps, incisal edges, marginal, transverse, oblique and other ridges of opposing teeth provide cutting blades or ridges, bearing opposing relationships to each other during the act of

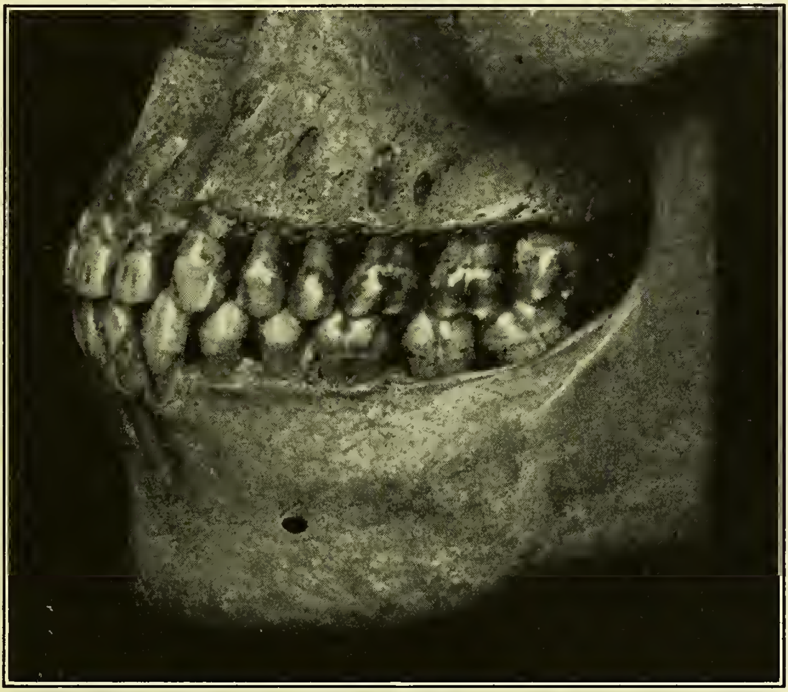


FIG. 478.—Normal centric occlusion of the left side. Almost straight "curve of Spee." Same skull as preceding.

mastication and functioning as shears to cut or crush the food held between them by the lips, cheeks and tongue. The occlusal surfaces of the bicuspids and molars present cusps, ridges, grooves and fossae which form a series of opposing convex and concave surfaces. The occlusal fossae and grooves and the interproximal embrasures provide for the free escape of the masticated food bolus, thus reducing the resistance to masticatory force. As stated, all opposing contacts are convex surfaces in fine, unworn dentures, when the teeth are in centric occlusion. Figs. 479 and 480.

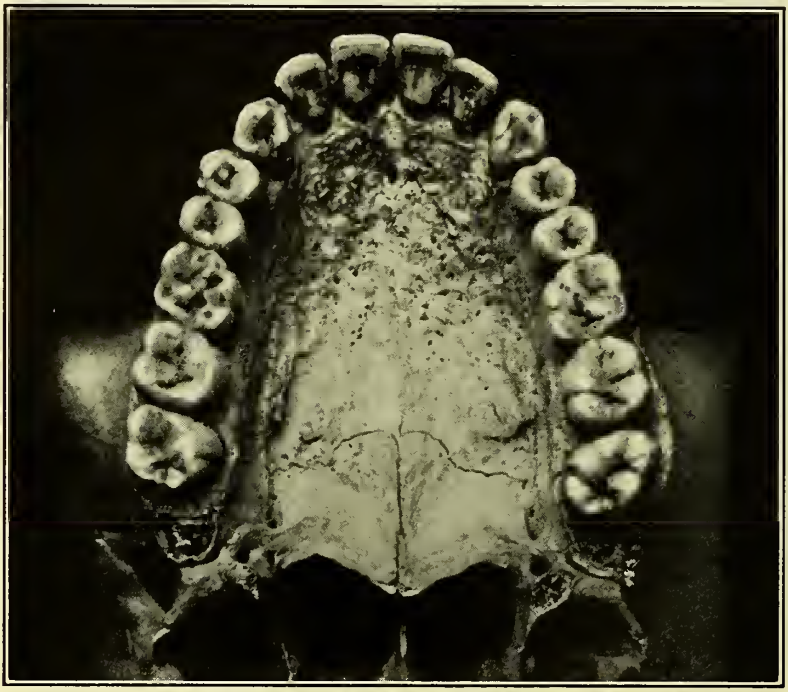


Fig. 479.—Maxilla and upper teeth.

The occlusal surfaces of these teeth represent a large number of mortars and pestles, the cusps and ridges representing pestles and the grooves and fossae, representing mortars, the pestles being smaller in size than the opposing mortars. This arrangement affords, in function, both a point contact and an incisive cutting effect. As a result of wear incident to age, the mortars and pestles become flatter and the contact areas are enlarged, thus diminishing the masticatory functions, increasing the resistance to the efforts and action of the muscles of mastication and also enlarging the excursions of mastication. In early life, the incisal edges of the anterior teeth and the occlusal contacting areas are sharp. At this time, the movements of the mandible are largely vertical. It does not need to travel far laterally. With increasing wear of the contacting surfaces the lateral excursions of the mandible are increased. The wearing of these contact surfaces and the cusps produces changes in all parts of the masticating machine, the facial tissues and the type of expression. Fig. 481.

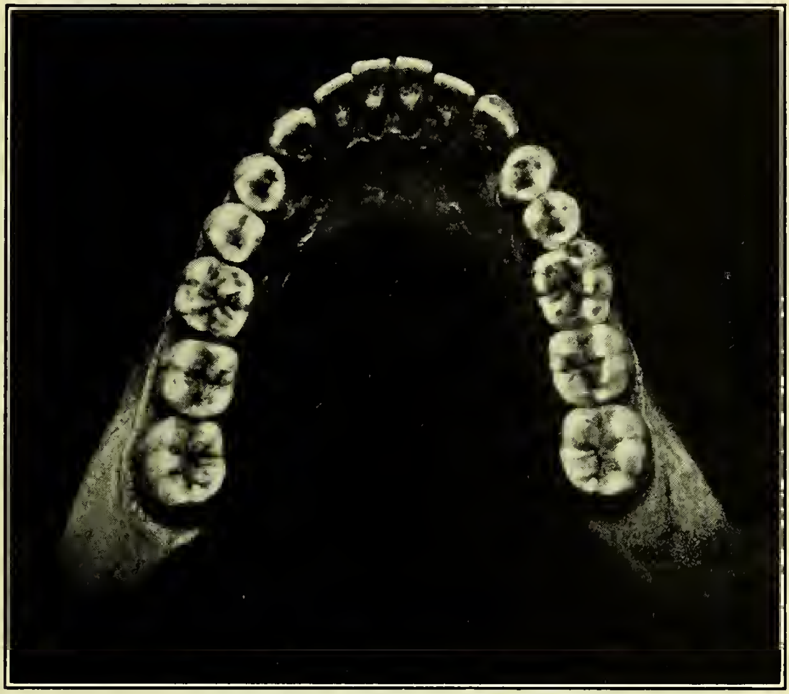


FIG. 480.—Mandible and lower teeth.

The arrangement, size and form of these anatomic landmarks should be so related to the various mandibular movements and to the curve of Spee that, during the act of mastication, undue stresses in all localities, vertical or lateral will be absent; else abrasion, traumatic occlusion, pericemental, gingival and pulpal disturbances will ultimately supervene. The functions of the contact points and contours of the proximal surfaces have previously been discussed, and the pathologic disturbances resulting from improper form in these localities have been described. A full understanding of all these facts is of the utmost importance in its bearing on restorative procedures in Operative Dentistry, since in all restorative

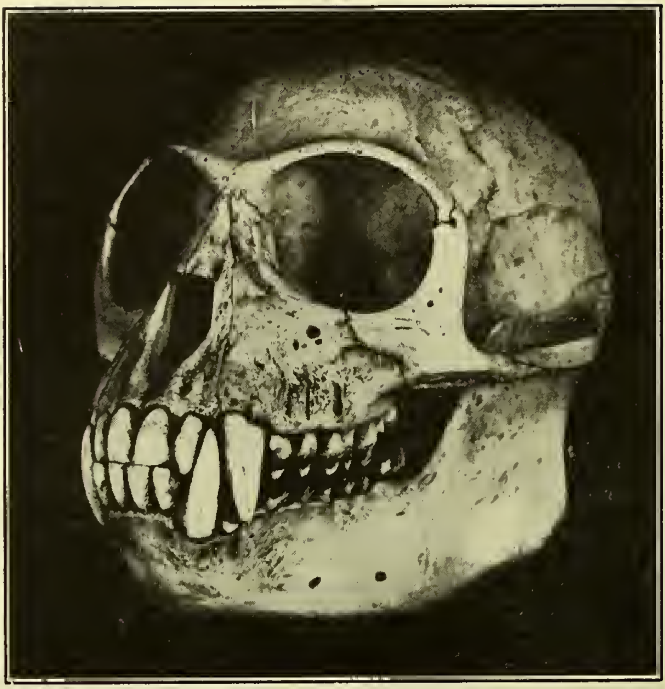


FIG. 481.—Presbytis Cephalopterus. Old world monkey. Age, adult.

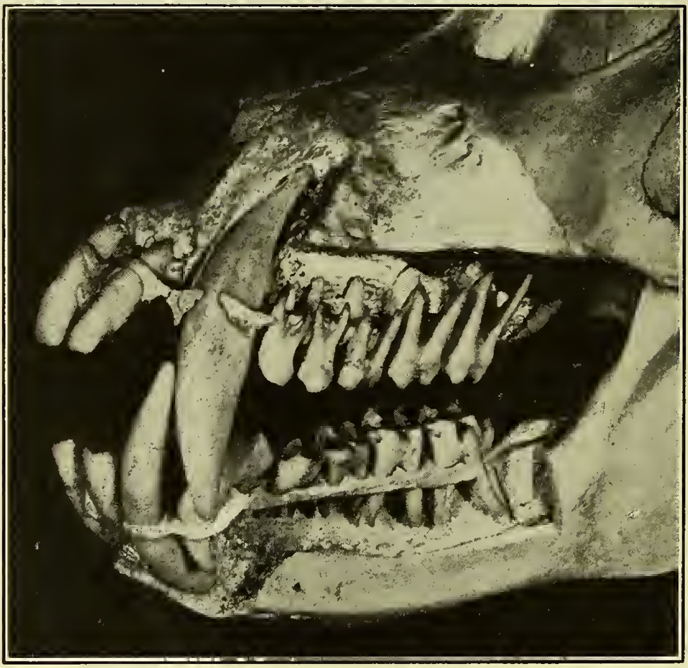


FIG. 482.—Cynocephalus Babouin. Dog-skulled Baboon. Gabon. Age, adult.

work the maintenance of fine anatomical form is a prerequisite to maintenance or restoration of function. Fig. 482.

THE FILLING OPERATION

A filling may be defined as a material so placed in the prepared cavity of a tooth that its physiological and mechanical functions, anatomical form, occlusion, contact point and esthetic appearance are properly restored or preserved, and the cavity is protected, as far as possible, from recurrence of decay.

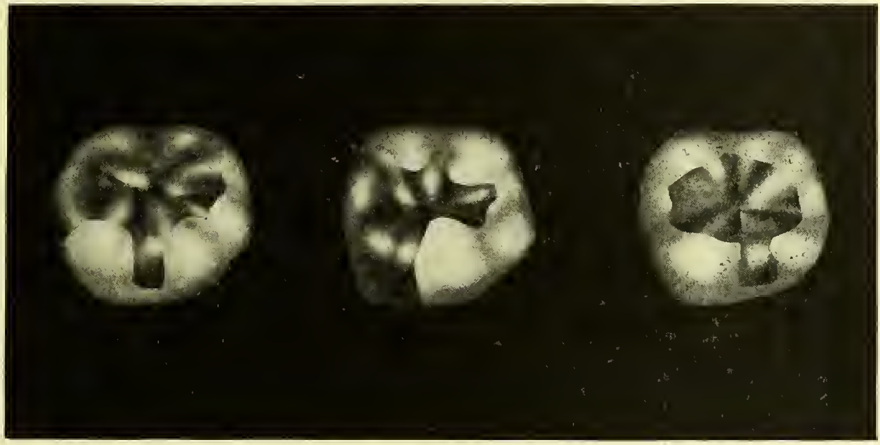


FIG. 483.—Fillings showing restoration of anatomical form.

There are several synonymous terms used to designate the filling operation, among which may be mentioned "obturation" and "stopping" (both of which are now almost obsolete in America), and "plugging," which is still used in referring to the gold building operation.

A study of the definition given will reveal the fact that a filling is not intended merely to plug a cavity of decay, as might be supposed by the beginner, but that the insertion of a properly-constructed restoration involves many very important considerations. As previously emphasized, the teeth as a machine are designed by Nature to perform many functions, and the best types are so constructed architecturally, that they are enabled to perform them to the highest possible degree and over long periods of time. In restoring lost tooth structure through the filling operation, these functions should be borne constantly in mind, and every effort should be made so to place and shape the restoration as to enable the tooth to perform those for which it was intended, or even to improve the conditions originally present. Restoration of the anatomic form, occlusal and approximal relationships and the masticating strength of the teeth is highly important. Fig. 483.

OBJECTS TO BE ATTAINED

The main objects sought to be attained in the filling operation are:

First.—Arrest of the loss of tooth substance from caries and other causes.

Second.—Prevention of recurrence of caries.

Third.—Restoration or maintenance of normal interproximal spaces and contact points.

Fourth.—Establishment of proper occlusion.

Fifth.—Accomplishment of esthetic effects.

Sixth.—Resistance against the stresses of mastication.

The ideal filling material has not yet been discovered. There are so many qualities necessary in a material designed for this purpose, that no substance or combination of substances yet devised, is capable of meeting all of them. It may be said that the attributes desirable are as follows, viz:

ATTRIBUTES OF AN IDEAL FILLING MATERIAL

First.—Insolubility in the fluids of the mouth.

Second.—Harmonious color.

Third.—Adaptability to cavity walls.

Fourth.—Great crushing resistance and edge strength.

Fifth.—Freedom from molecular change.

Sixth.—Non-conductivity.

Seventh.—Capability of polish.

Eighth.—Convenience of manipulation.

An ideal filling should be insoluble in the fluids, acids, and other substances present in the mouth. It should not offend the esthetic sensibilities of refined individuals. The placing of conspicuous gold building operations in exposed positions in the mouth is an insult to the artistic susceptibilities of cultured patients, as well as a reflection on the intelligence and character of the man who performs the operation. A filling material should be of a consistence which will admit of convenient and ready manipulation and easy adaptation to the cavity walls. It should be capable of resisting the stresses of mastication, which frequently are very great, and it should not change its form after introduction. It should also be a relatively good insulator to thermal and electrical changes, and it should be capable of taking the high polish of the enamel of the tooth in which it is placed, else there will be a tendency to the accumulation of food debris on its surface. The finished operation should be continuous with the surface on which it is placed, so that the exploring tine, when passed over its margins at any point, may not detect the slightest irregularity of continuity. The dental profession is still in search of a material which adequately will fill all of these requirements.

The selection of a filling material for individual cases is a matter of mature judgment, which is only obtained through long experience. The conditions which have to be taken into consideration, and which will regulate the choice of material may be enumerated as follows, viz.:

CONDITIONS REGULATING THE SELECTION OF A FILLING MATERIAL

First.—Age of the patient.
Second.—Friability of the enamel.
Third.—Sensitivity of the dentin.
Fourth.—Physical condition of the patient.
Fifth.—Hygienic condition of the mouth.
Sixth.—Strength and character of the bite.
Seventh.—Esthetic appearance.
Eighth.—Mentality and will-power of the patient.
Ninth.—Expense of the operation.

Young and old patients frequently are incapable of bearing the strain incident to prolonged and difficult gold building operations, therefore some other material has, frequently, of necessity, to be chosen. The enamel in some teeth is of such a brittle nature that it may be deemed inadvisable to attempt a cohesive gold operation, requiring the application of great force. In some instances, the dentin of the tooth operated upon is in such a hypersensitive condition that the dentist may not be justified, at the time, in inserting a material requiring extensive cutting during the preparation of the cavity. Patients whose physical condition is, at the time, below par are occasionally incapable of subjection to extensive filling operations, the condition sometimes necessitating a temporary operation. In habitually unclean mouths, gold is the material *par excellence*, as far as its lasting qualities are concerned. The silicates and other plastics will succumb much more rapidly under these conditions. Surfaces subjected to great masticatory power require materials capable of withstanding the stress, while those exposed to view demand inconspicuous colors. Patients of low mentality and will-power frequently will refuse to subject themselves to operations requiring long time or producing mental and nervous strain. The economic aspect of the operation has, of necessity, frequently to be considered. A comprehensive knowledge of the properties and the technic of manipulation of the available filling materials also is necessary before an intelligent selection can be made for individual cases. These will now be discussed.

Filling materials may be classified according to their lasting qualities and their working properties. The following classifications usually are made:

CLASSIFICATION OF FILLING MATERIALS

First.—From the standpoint of their lasting qualities into
  (1) Temporary: (*a*), Cement; (*b*), Guttapercha.
  (2) Permanent: (*c*), Gold; (*d*), Amalgam; (*e*) Tin.
Second.—On the basis of their working properties into
  (1) Plastics: (*a*), Amalgam; (*b*), Cement; (*c*), Guttapercha.
  (2) Non-plastics: (*d*), Gold: (*e*), Tin.

THE TEMPORARY FILLING MATERIALS

GUTTAPERCHA

Guttapercha is the purified concrete juice obtained by tapping the Isonandra Gutta, an evergreen tree of the order of Sapotaceae, found principally in the Malay Peninsula and Archipelago. It also is derived from other varieties of gutta found in tropical countries. Chemically, it consists of a hydrocarbon (pure gutta), $C_{10}H_{16}$; albane, $C_{40}H_{64}O_3$; and guttane, a compound of variable composition, thus somewhat resembling rubber in origin and composition.

Its color is almost white, rose, or grayish-white. It is inodorous, slightly elastic, and contracts markedly on hardening or cooling. It is very bland and unirritating to the soft tissues, and is a relatively good non-conductor. It in time becomes porous and disintegrates in unclean mouths. It is freely soluble in chloroform, while oil of eucalyptus, eucalyptol and oil of cajuput have a softening effect upon it. It also is soluble in carbon bi-sulphid, coal tar oils, benzol, boiling ether and oil of turpentine, while under normal conditions it is insoluble in dilute acids and concentrated alkaline solutions. Heat softens it, but it hardens again on cooling. Guttapercha is not used in its pure state for filling purposes. It is combined with white wax, zinc oxid, calcium oxid, and other substances to give it desirable working qualities. It was introduced into Dentistry as a filling material about 1847, Hill's Stopping being one of the earliest preparations for filling purposes.

CLASSIFICATION AND FORMS USED

As used for filling purposes guttaperchas may be classified into low, medium, and high heat, depending on composition and working properties.

Low heat guttapercha softens below 200°F. Its formula is usually about 1 part guttapercha, 4 parts zinc oxid.

Medium heat guttapercha softens from 200° to 212°F., its formula containing 1 part guttapercha, 6 or 7 parts zinc oxid.

High heat guttapercha softens from 210° to 225°F. and contains zinc oxid to saturation.

Some prominent varieties of guttapercha used in operative dentistry are:

Excelsior Guttapercha; high heat; (softens at 225°F.).

Premium Guttapercha; medium heat; (softens at 208°F.).

Superior Guttapercha Stopping; high heat.

Flagg's Guttapercha Stopping; supplied medium heat, high heat, or low heat.

White Base-Plate Guttapercha; medium heat.

Pink Base-Plate Guttapercha; medium heat.

Hill's Stopping.

The formula of Hill's Stopping, which has been used in Dentistry many years is, according to Herman Prinz, feldspar, 1 part; quartz, 1 part; quicklime, 2 parts; guttapercha base plate q.s. to make a stiff paste.

Other forms are (1) Temporary Stopping or Dressing Seal, low heat; (formula, white or pink base-plate, 4 parts; zinc oxid, 4 parts; white wax, 1 part), for sealing temporary dressings in teeth and (2) Guttapercha Points for filling canals.

The **advantages of guttapercha** as a filling material are:

First.—Relative non-conductivity.

Second.—Ease of introduction.

Third.—Harmonious color (the white varieties).

Fourth.—Slight elasticity (an advantage in making slow separation).

Its **disadvantages** are:

First.—Low crushing resistance. For this reason, it cannot be used as a permanent filling material on surfaces exposed to mastication.

Second.—It is subject to chemical action of lactic acid and sulphids in unclean mouths, readily disintegrating.

Third.—Shrinkage on cooling, with consequent tendency to draw from cavity walls during manipulation.

Fourth.—Incapability of polish.

Uses of Guttapercha.—It may be used as a temporary filling material in deciduous teeth and as a more or less temporary filling material in unexposed cavities in permanent teeth. It is valuable for sealing in dressings and for temporarily sealing cavities before insertion of inlays or fillings, for producing slow separation of the teeth, for filling root canals and for temporarily setting crowns and bridges. In the form of chloropercha (a solution of guttapercha in chloroform made to a creamy consistency) it is used for filling small pulp canals, and by some as a cavity lining.

Although guttapercha has many undesirable properties, it still has its uses in modern dental practice. However, for filling teeth, it has been largely supplanted by the cements. The modern demands of oral hygiene for a material which is capable of maintaining a high polish and which will not absorb the products of fermentation and putrefaction have greatly reduced its use. Also, the demands of orthodontists for restoration of normal contact points in the deciduous teeth have gradually militated against its use in proximal cavities in these teeth. For these reasons, it should not be exposed to the oral fluids for any great length of time, except under very exceptional circumstances. Pink base plate guttapercha, where its color is not objectionable seems better to resist the action of the products of fermentation and putrefaction, due supposedly to its sulfid of mercury content.

Guttapercha is valuable for sealing prepared cavities against moisture during inlay work, and also where a filling is not to be inserted at the same sitting. On account of its elasticity it may produce undesirable pressure against thin pulpal walls in deep-seated occlusal cavities and also is likely to act as a cushion and force medicaments through the apical foramen, with consequent periapical disturbance, if used for sealing dressings on occlusal surfaces in root therapy operations. For these reasons, cements will usually be better under these circumstances. When, for any reason, it is not desired to permanently cement into position a crown or bridge, it may be used to temporarily set them with guttapercha for a few days. Its use as a cavity lining has been largely superseded by the modern cavity linings or varnishes. Its use as a root canal filling material is discussed in the proper place. Its value as a slow separating material has already been mentioned.

METHODS OF MANIPULATING GUTTAPERCHA

Give the cavity retentive form, omitting strong cavo-surface bevels, which would necessitate building the material out to thin feather edges.

Before insertion, the walls may be slightly moistened with eucalyptol, oil of eucalyptus, or oil of cajuput, preferably the first agent mentioned. This will slightly soften the guttapercha and increase its adhesiveness. Avoid over-heating the guttapercha, as the product is thus easily injured. Heating may be accomplished over the alcohol lamp, Bunsen burner, special forms of heater designed for the purpose, such as the "Thermoscopic Heater," or on a piece of soapstone or small porcelain tray laid over an electric annealer. For filling, adopt one of the following methods:

First Method.—Cut the guttapercha into small pieces with a hot, thin-bladed spatula, soften with heat and pack each piece separately, condensing thoroughly with cold smooth burnishers of suitable size. Avoid much excess, as the material is rather difficult to remove. Remove surplus material immediately with a hot, flat spatula or burnisher, trimming toward the margins. Smooth the surface of the filling with the same instrument, slightly warmed. If preferred, the filling may be allowed to cool and harden thoroughly, when the excess is removed with a sharp knife blade (Black), but the knife must be very keen, to avoid drawing the filling away from the margins.

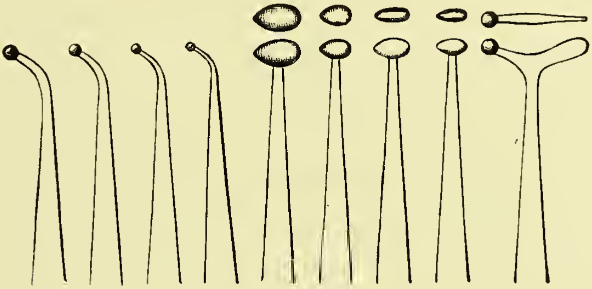


FIG. 484.—Burnishers.

Second Method.—In cavities of easy access, heat the guttapercha and, while soft, mold into a mass of sufficient size to fill the cavity, packing with a warm smooth burnisher, condensing thoroughly against the walls, and trimming the excess after either of the above methods. Then go over the surface of the filling with a pledget of cotton or spunk, moistened with chloroform in order to give it a smoother finish. Fig. 483.

THE CEMENTS

The cements consist of a powder and a liquid. These, when mixed by the dentist, form a plastic mass, in which state introduction into the cavity is accomplished, following which, setting or hardening occurs.

The chemical composition of dental cements has been, up to recent years, largely a trade secret. However, much valuable information has been recently gained as to their physical chemistry. At the present writing, the Research Commission of the American Dental Association at the National Bureau of Standards is still engaged in an investigation of dental filling materials. Their reports on dental cements have appeared in the Journal of the American Dental Association on several occasions during and since 1933. The reports of the valuable work of the Bureau, on dental amalgams, cast and wrought golds and solders, investments, waxes, etc., are mentioned in the proper place. The work of this Bureau has been the means of placing the manipulation of these materials by the dentist on a more scientific basis. Also it has resulted in producing a closer cooperation on the part of the better type of manufacturers in the production of acceptable products and in an exposure of those concerns who produce defective and undesirable materials.

CLASSIFICATION AND GENERAL COMPOSITION OF CEMENTS

The dental cements in use at the present time are the oxyphosphate of zinc, oxyphosphate of copper and the silicate cements. In general, their basic composition is as follows:

Oxyphosphate of Zinc Cement: *Powder.*—Zinc oxid (calcined).

In some cases modifiers, such as bismuth oxid up to 4.5 per cent and magnesium oxid up to 13.0 per cent are added. See Table 4.

Liquid: Phosphoric acid solutions buffered with varied amounts of zinc oxid and aluminum hydroxid. See Table 5.

Oxyphosphate of Copper Cement: Powder—Cupric Oxid plus zinc oxid. Liquid—Phosphoric acid, buffered with cupric oxid.

The silicates: Powder—Silica, Alumina, and Fluxes. Liquid—Phosphoric Acid.

From these three basic types, many varieties of cements have been evolved and are being produced for the profession by the various manufacturers. Although the basis of the powder and liquid is as given, many additional substances are added as modifiers to produce desirable or necessary characteristics.

The first dental cement of which we have any knowledge was a zinc oxychlorid, the powder being zinc oxid and the liquid consisting largely of zinc chlorid. Cements of this type came into use about 1859. Owing to their permeability and irritating properties, they soon fell into bad repute, and may now be considered as almost obsolete. The possibility of the use of phosphoric acid as the mixing fluid had been suggested as early as 1832, following which, experiments were made, extending over many years by numerous investigators, toward the introduction of a zinc oxyphosphate. It was found that owing to the great chemical affinity of zinc oxid and phosphoric acid, setting of this mixture occurred too rapidly, and consequently sodium phosphate was added. This retarded the setting, but greatly increased the solubility and porosity of the material. Other substances were then added from time to time to increase strength and to reduce the solubility of the sodium phosphate. Owing to lack of success in this direction, sodium phosphate is no longer used as a modifier in the best type of cements. The first zinc oxyphosphate introduced into America was known as Weston's Insoluble Cement and was announced in 1879. Since this time, many changes in formulae have been made and material advancements have occurred in our knowledge of the chemistry of cements. Many independent investigators and the various manufacturers have contributed to the knowledge of the subject and, although there are today many cheap and useless preparations of this nature on the market, it must be admitted that the better type of manufacturing concerns are still endeavoring to improve their product and to present materials scientifically constructed. The first successful oxyphosphate of copper cement (black) was introduced by W. V. B. Ames, which was followed by the red copper cement of Fleck and later by so-called light colored cements of Caulk and others. The silicates were presented in 1908 and silver germicidal cements (modified zinc oxyphosphates) in 1918.

TABLE 3.—SUMMARY OF DETAIL REQUIREMENTS OF A. D. A. SPECIFICATION No. 8 FOR DENTAL CEMENTING MEDIUM

Consistency of Mix	Time of Setting at 99 F.		Ultimate Compressive Strength		Film Thickness	Disintegration
	Min.	Max.	Min.	Min.	Max.	Max.
	Minutes	Minutes	1 Hour	7 Days		
			Kg. sq. cm.	Kg. sq. cm.	Microns	Per cent by weight
Disk 30 ± 1 mm. in diameter	4	10	350 (Lb. sq. in.) (5,000)	840 (Lb. sq. in.) (12,000)	50	1.0

As of January 1, 1936 the following list of zinc oxyphosphate cements were found by the Research Commission of the American Dental Association to comply with the American Dental Assoc. Specification No. 8.

SECOND SURVEY OF ZINC PHOSPHATE CEMENTS

Cement	Manufacturer or Distributor
Ames, Z-M	The W. V-B Ames Co.
Caulk, Crown and Bridge	The L. D. Caulk Co.
Caulk, Tenacin	The L. D. Caulk Co.
Smith, Certified	Lee S. Smith & Son Mfg. Co.
S. S. White, Zinc	The S. S. White Dental Mfg. Co

GENERAL CHARACTERISTICS AND USES OF CEMENTS

Zinc Oxyphosphates are used for temporary fillings, as intermediates, and for cementing crowns, bridges, inlays, and orthodontia appliances. With the exception of the silicates, they are the most important of the cement preparations and the most universally used. They are made in various shades to match the color of the teeth and are much more lasting than were the oxychlorid of zinc preparations.

Oxyphosphate of copper cements are claimed to be antiseptic and markedly bland to sensitive dentin. They are used for filling cavities, pulp chambers and canals in temporary teeth, and also cavities in permanent teeth, the sensitiveness of which will not permit of proper cavity preparation. Many of these cements are of an inky black or red color, but more recently introduced specimens are being supplied in various shades of white, gray, and yellow. These latter, however, are really oxyphosphates modified by the addition of small percentages of copper salts.

The silicate cements are yet in a stage of experimentation, but marked improvements have recently been made in their qualities. In no sense should they be classed as permanent filling materials, although there is a great variation in the results claimed by different operators. They are transluscent, and match the color and appearance of enamel more nearly than any other material yet introduced. Some of them have been claimed to be markedly irritating to vital tissue, and consequently should be preceded by a non-conducting varnish or an intermediate. The crushing resistance of some far exceeds that of others. Among the more prominent ones may be mentioned S.S. White Filling Porcelain, Smith's Certified Enamel, deTrey's Synthetic Porcelain, Ames' Berylite, and Baker's Durenamel.

The Research Commission of the A.D.A. at the National Bureau of Standards is engaged in an investigation of silicate cements. The report of this research is not available for publication at this writing.

Advantages of Cements.

First.—Comparative non-conductivity.

Second.—Harmonious color (except oxyphosphate of copper, some of which is black or red).

Third.—Comparative adhesiveness to cavity walls (except silicates).

Fourth.—Ease of introduction.

Fifth.—Antiseptic properties (copper and so-called silver).

Disadvantages of Cements.

First.—Lack of edge strength.

Second.—Low crushing resistance.

Third.—Solubility in the fluids of the mouth.

Fourth.—Incapability of polish (except silicates).

Fifth.—Tendency to change of molecular form, while setting.

Sixth.—Tendency to heat production during setting.

CHEMICAL PHENOMENA

The intelligent use of cements requires an appreciation of the chemical phenomena involved in the reaction between the powder and the liquid when mixed. During their union, heat is generated, strength and solubility are affected and working properties and other characteristics, such as adhesiveness, antiseptic property and expansion are regulated, depending on the constituents of the powder and liquid and the method of manipulation.

Reactions occurring between solids and liquids are known as heterogeneous reactions, because the reacting substances exist in different states or phases. The laws governing these reactions are rather complicated and have been combined in what is known as the Noyes-Whitney equation. This equation will not be discussed here, but the practical application of some of these laws will make clearer some phases of the setting process in dental cements.

The first of these laws provides that when a solid substance is attacked by a liquid, the rapidity of action will be dependent on the size of the surface attacked. In dissolving substances in water, acceleration of the solution is accomplished by crushing the substance into small particles. In a dental cement, the finer the powder is ground, the more quickly will the cement set. Thus it is demonstrated that the "reaction velocity is directly proportional to the surface of the solid." This law is taken advantage of by the manufacturers in grinding the powder.

The second law states that a metal dissolves more rapidly in a strong than a weak acid, the rate of the reaction depending on the quantity of active constituent in the acid solution, viz. its "initial concentration." In dental cements, if the initial concentration of the acid is very strong, the reaction velocity will be too great and setting will occur too rapidly. This is controlled by the manufacturer by adding some of the constituents of the powder, as well as other substances to the liquid to reduce its concentration and the reaction velocity. This in reality produces an initial or first stage of setting in a dental cement. A second stage of setting is under the control of the dentist in mixing powder and liquid together. Applying the first law of reaction, if a large portion of powder is drawn into the liquid, thus exposing a large surface to the action of the acid in the liquid, a rapid reaction occurs and quick setting results. If small portions of the powder are drawn in and thoroughly spatulated, the reaction velocity is retarded and slow setting occurs.

TABLE 4.—COMPOSITION OF ZINC PHOSPHATE CEMENT POWDERS (PERCENTAGE BY WEIGHT)*

Sample	ZnO	MgO	SiO_2	R_2O_3	Bi_2O_3	Miscellaneous
A	100.0	....	0.05	0.05	....	
B	99.7	....	0.1	0.1	....	CaO, 0.1
C	98.0	....	....	....	1.9	
D	99.4	....	0.6	0.1	0.04	
E	92.4	7.5	0.1	0.06	....	CuO, 0.1
F	90.3	8.2	1.4	0.1	....	
G	90.2	9.4	0.4	0.07	....	
H	89.9	9.1	0.4	0.5	....	
I	89.5	9.4	0.3	....	....	$BaCrO_4$, 0.8
J	89.3	9.4	0.3	0.1	....	CuO, 0.02; $BaCrO_4$, 1.0
K	88.0	9.4	0.8	....	1.8	
L	89.1	4.0	1.8	0.5	4.5	
M	82.2	9.0	3.0	0.9	4.1	CuO, 0.8
N	83.1	7.2	0.1	0.04	....	$BaSO_4$, 8.2; BaO, 1.3
O	84.0	7.2	4.9	1.0	....	CaF_2, 2.7
P	74.9	13.0	1.3	2.6	....	CaO, 2.2; B_2O_3, 5.1
Q	9.4	....	36.5	26.3	....	F, 12.0; Ca, 5.9; Mg, 0.5; Na, 4.6; P_2O_5, 3.2; ignition loss, 6.9

* Table of Research Commission, A.D.A.

The third stage of setting occurs after the filling is placed in the cavity, and the type of this reaction and the results produced are dependent largely on the reactions provided for in the first and second stages. Thus it is seen that the first stage is under control of the manufacturer.

the second stage is largely regulated by the dentist, while the third stage is dependent on both.

The Liquid.—As has been mentioned, the principal constituent of the liquid in all three classes of dental cements is phosphoric acid. If commercial zinc oxid be mixed with concentrated phosphoric acid, an instant reaction occurs, great heat being evolved and the mass setting rapidly, forming a porous, friable cement. Thus it becomes necessary to retard this reaction in order to allow for proper manipulation before hardening of the mass. This is accomplished by modifying both the liquid and the powder. In most modern oxyphosphate cements, the liquids are solutions of phosphoric acid, water, zinc oxid, and aluminum hydroxid. See Table 5.

TABLE 5.—COMPOSITION OF ZINC PHOSPHATE CEMENT LIQUIDS (PERCENTAGE BY WEIGHT)*

Sample	Analysis				Calculations			
	PO_4	Al	Zn	Mg	Free H_3PO_4	Combined H_3PO_4	Total H_3PO_4	Phosphate
A	57.4	1.8	10.0	...	42.8	16.6	59.4	27.8
B	55.2	3.4	3.1	...	41.6	15.5	57.1	21.5
C	64.3	2.7	....	...	56.8	9.8	66.6	12.2
D	57.3	2.1	10.0	...	41.7	17.6	59.3	29.2
E	64.6	2.7	1.6	...	55.5	11.4	66.9	15.4
F	52.6	2.5	7.1	...	38.2	16.2	54.4	25.3
G	59.9	2.9	2.0	...	49.4	12.6	62.0	17.0
H	59.7	2.1	4.1	...	50.1	11.7	61.8	17.6
I	57.9	2.8	....	0.3	48.9	11.0	59.9	13.7
J	61.1	2.8	....	...	53.1	10.2	63.3	12.7
K	64.0	3.2	....	...	54.7	11.6	66.3	14.5
L	64.2	2.7	0.9	...	55.8	10.7	66.5	14.0
M	67.2	3.0	....	...	58.7	10.9	69.6	13.6
N	64.9	2.9	....	...	56.6	10.6	67.2	13.1
O	54.6	2.3	10.3	...	37.8	18.7	56.5	30.7
P	53.4	2.7	....	...	45.5	9.8	55.3	12.2
Q	47.9	1.9	4.4	...	38.3	11.3	49.6	17.3

* Table of Research Commission, A.D.A.

The Powder.—The composition of the powder varies, depending on whether the cement is a zinc, copper or silicate combination.

Zinc Oxyphosphates.—In this type of cement the basic constituent of the powder is zinc oxid. Zinc oxid of commerce is a light, fluffy powder of low specific gravity. In order to decrease the surface exposed to the action of the liquid and prevent too rapid a chemical reaction, the product is subjected to calcination at high temperature or to nitration. The calcination process consists of fusing the zinc oxid at very high temperature, crushing and grinding the resulting ingot into powder. The addition of magnesium oxid or bismuth oxid allows calcination to occur at lower temperatures and reduces the cost. See Table 4.

Copper Oxyphosphates.—The powders of these cements are presented in black, red, white, light brown, greenish, and yellowish shades. With the exception of the black oxyphosphate of copper cement of Ames, which is supposed to consist of 99% pure cupric oxid, most of the other so-called copper cements are modifications of the oxyphosphate of zinc powder. Another prominent black copper cement contains 25% cupric oxid added to zinc oxyphosphate powder. The majority of the red copper cements are modifications of the zinc oxid powder by the addition of approximately 25% cuprous oxid. The copper cements of lighter shades contain small percentages of cuprous iodid, cupric silicate or of similar substances. The use of copper salts in these cements is for the purpose of giving them antiseptic properties. Tests have shown that the light colored copper cements possess very little of this property, while the black and red preparations are supposedly highly antiseptic, owing to high copper content.

Silver Cements.—Recently introduced germicidal cements contain silver chlorid or silver phosphate in small amounts in the regular zinc oxid powder. Both of these agents are claimed to have high germicidal efficiency, to be active on albumen in the presence of moisture and to be very slightly soluble in water, but to be subject to discoloration in the mouth. Those containing silver chlorid are less active germicidal agents than those with the silver phosphate constituent, are less soluble and discolor less readily, turning to a light gray color. Those containing silver phosphate are more soluble, hence, less permanent in character, cause discoloration of tooth structure, a blue gray color, but have higher germicidal power. No substantial evidence has been produced to prove that these preparations are superior to copper cements, except that they produce less discoloration than the black or red copper cements.

INTERMEDIATES AND CAVITY LININGS

Sensations of heat and cold are rapidly transmitted, by means of the dentinal fibrillae, to the pulp from the walls of cavities, and, as many of the filling materials are conductors of these physical forces, it becomes necessary in all cavities, except extremely shallow ones, to place relatively non-conducting substances between the filling and the walls of the cavity. These materials are known as intermediates or bases, and the act of placing them in position is known as Pulp Protection. The substance most frequently used is oxyphosphate of zinc cement. Cement itself is a slight conductor, so that in extreme cases of hypersensitivity one of the cavity linings, such as chloroform rosin solution or cavity varnish, is applied and then covered with cement, when the balance of the filling is placed in position. Cavity linings and varnishes should be good non-conductors, protect the fillings from loss of water, and protect the pulp from chemical or irritating substances of any kind. Fig. 485.

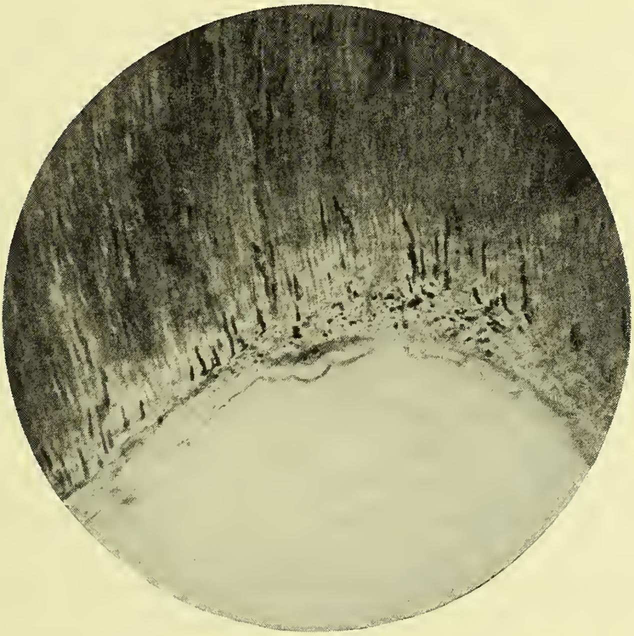


FIG. 485.—Dentin above, pulp chamber below. Entrance of tubules into dentin is seen in transverse and longitudinal section. (Courtesy of Dr. John B. Stein.)

Cavity linings are colorless, transparent liquids, which on evaporation leave a thin, non-conducting film on the walls of cavities. Cavity linings also may be used under gold crowns to prevent the transmission of sensations to the pulp in vital teeth.

SILICATE CEMENTS

The first of these cements was introduced into dentistry in 1908. Although many changes have been made in their composition and improvements accomplished in their properties, they can still be considered only as temporary filling materials. Although they possess the important characteristic of translucence and, when properly mixed and inserted, present such a harmonious blend with natural tooth structure that their presence is hard to detect, they still possess the disadvantages of easy solubility in the fluids of the mouth and lack of crushing resistence.

The liquids of these preparations are similar to those of the zinc cements, differing chiefly in the amount of water contained. They consist principally of orthophosphoric acid and water with zinc oxid and alumina as modifiers. Some of the earlier silicate powders were made by precipitation, but this method has been abandoned in favor of fusion and crushing. They are now made by fusing together silica, alumina and fluxes at a temperature of about 1,400°C. producing a glass which is then crushed and ground to a fine powder. Such substances as beryllium silicate, calcium silicate, calcium borate and soda-lime glass have been used as fluxes, but on account of low translucence these have largely been abandoned. According to Crowell,[1] calcium fluoride is now used as the flux in most of the silicate powders manufactured in the United States.

Mixture of the liquid and powder liberates silicic acid, which is in the power probably attached to its alumina constituents. This substance is largely responsible for the desirable or undesirable properties of silicate cements. Setting of the mass is due to gelation of the silicic acid, which is an irreversible colloid, while with the zinc cements setting is a crystallization process. The translucence of the cement depends largely on the refractive index of the powder. This must be kept low and close to that of silicic acid. This is accomplished through the presence of substances of low atomic weight, such as salts of fluorin, previously mentioned, or of beryllium or boron.

GENERAL PROPERTIES OF CEMENTS

Much has been written with reference to the presence of arsenic as an impurity in cements. Modern methods of manufacture have eliminated the possibility of its presence, certainly in the better grades of cements, even the silicates. If present at all, arsenic would be found only in the cheaper grades of cement. In all the cements which complied with the American Dental Association Specification No. 8 the powders and liquids were found to conform to the requirements prescribed by the U. S. Pharmacopeia XI regarding arsenic content (less than 1 part to 100,000).

The fineness of the power has a definite effect on the rate of setting of cements. The finer the powder is ground, the quicker it sets. Fineness of the powder also regulates to some extent the strength of cements. The particle size of powders from the dental standpoint, is of importance only in relation to film thickness. Since cast crowns and inlays are now accurately made, their proper seating requires a thin layer of cement. (Paffenbarger et al., Jour. A.D.A., Nov. 1934). The amount of calcining of the zinc oxid also has a definite effect. When heated to a comparatively low temperature, it will produce a soft and sticky cement, while a hard, flint-like but less adhesive cement is the result of a great amount of calcining.

It is important to keep the bottles of powder and liquid tightly stoppered, in order to avoid crystallization of and loss of water in the liquid and absorption of water from the atmosphere by the powder. Telescoping cap bottles should be used, to prevent this tendency as far as possible, and bottles should be stoppered immediately after use. The liquid is much more susceptible to change, due to the humidity of the air, than is the powder.

It should be realized that when liquid and powder are mixed a definite chemical reaction occurs. If constituents of powder or liquid are changed by addition or loss of water, or impurities, rate of setting, volume changes, porosity, crushing resistance or shade may be affected. The activity of the liquid may be changed markedly by variation of the amount of phosphoric acid it contains, and this may be regulated by the amount of water present. Absorption of water from the atmosphere by the powder will be likely to change the characteristics of the mixed cement. Powder and liquid, as dispensed by the manufacturer, contain definite proportions of definite constituents, which have been tested to give a definite reaction, when mixed. When delivered to the dentist, they really represent an arrested chemical reaction, which is properly completed on mixing in the proper manner and to the exclusion of any additional substances.

Stability of Form and Volume.—The better grades of cements are intended to be as free from volume change as possible. All of the cements formerly tested by the Research Commission of the American Dental Association shrank upon setting. Cements showing excessive shrinkage are undesirable. A carefully manufactured cement possesses an equilibrium which gives it constant volume for a given temperature.

Hydraulicity of Cements.—This term has been applied to certain cements which are supposed to set properly in the presence of moisture. In view of our present knowledge of the chemistry of the dental cements, it cannot be properly applied to any of the oxyphosphates or silicates. During the reaction occurring in the mixing process, the soluble acid phosphates of the liquid are present until initial hardening is complete. Until these have combined with the powder and become fixed or insoluble, exposure to moisture will dissolve a portion of them and cause eventual disintegration. Consequently, absolute dryness is essential in their manipulation until initial setting is complete. Complete setting is a very slow process with the silicates, which require exclusion of moisture for at least 24 hours to 36 hours. With the oxyphosphates, exclusion of moisture for a much short time is necessary before the "hydraulic state" is reached, when moisture may be admitted. This time varies with different products, depending on rapidity of setting, which latter varies greatly, depending on manner of mixing, chemical composition, heat evolvement, etc. The rate of setting is also dependent, to quite a degree, on the amount of water in the liquid. Some manufacturers furnish liquids marked rapid, medium and slow setting. Hydraulicity is less marked with the use of the slow setting liquids, which evidently contain higher percentages of water. Hydraulicity of cements is undoubtedly changed by undue exposure of powder or liquid to an atmosphere containing much moisture. After complete setting of cements has occurred they are then hydraulic, being constantly bathed in the fluids of the mouth. Silicate cements particularly require the constant presence of moisture for the maintenance of their integrity. If water is excluded even for a short time, deterioration occurrs. Mouth breathers are subject to "dry-mouth," particularly during sleep, hence the silicates show rapid disintegration in patients of this type.

Solubility of Cements.—Easy solubility in the fluids of the mouth is one of the greatest weaknesses of this type of filling material. The solubility of cement in saliva, when combined with the resultant disintegration of the cement, is used as a measure of the permanence of the cement. The combined effect of solubility and erosion has been called the disintegration of the cement. Variation in the solubility may be due to several causes, such as composition and mode of production, method of mixing and insertion, consistency of the mass, imperfect exclusion of moisture from the field of operation and presence of pigments. Disintegration is accelerated through the action of lactic acid, ammonia, and ammonium chlorid resulting from fermentation and putrefactive processes in the mouth. Mucin has a restraining influence. Porosity, resulting from improper manipulation or manufacture, necessarily increases the tendency to solubility, invites absorption of mouth secretions, reduces crushing resistance and increases the possibility of disintegration.

Adhesiveness of Cements.—The silicates possess no adhesive properties, while the zinc oxyphosphates possess this property only in the smallest degree. The reason that so strong a retention is obtained between a gold crown or inlay and the tooth substance is explained by the fact that the cement flows into all the irregularities of the tooth and the appliance and locks the inlay or crown in place. The tremendous force required to dislodge the appliance from the tooth is accounted for by the shearing or crushing strength of the cement powder particles. The relation of the compressive or crushing strength of cements with time is shown by the following table.

TABLE 6.—COMPRESSIVE STRENGTH* WITH TIME†

Cement‡	Time				
	1 Hour	3 Hours	1 Day	1 Week	4 Weeks
F§	10,000	11,500	13,000	16,000	17,500
F‖	11,000	13,000	14,500	15,500	15,000
K§	10,000	10,000	16,500	17,000	16,500
K‖	10,500	10,000	15,500	16,000	16,500

* Pounds per square inch.

† Table of Research Commission, A.D.A.

‡ Mixes made with 1.50 gm. of powder to 0.50 c.c. of liquid.

§ Specimens were immersed in liquid petrolatum.

‖ Specimens were immersed in distilled water.

Germicidal Properties of Cements.—Much has been written with reference to this subject. So conflicting are the statements and claims made by various investigators that no very definite information is available. The reader is referred to articles of Marcus L. Ward,[2] W. V. B. Ames,[3] Paul Poetschke,[4] M. R. Smirnow,[5] Raymond F. Bacon,[6] and C. Jane Fraser,[7] while the matter is also discussed in the voluminous literature of the manufacturers. Variations in the findings reported are due to differences in laboratory technic or to trade influence. The present investigation of Cements by the U. S. Bureau of Standards will undoubtedly include this phase of their reactions.

At present it is conceded that all cements, while in the plastic state, possess some antiseptic properties, due to the presence of uncombined phosphoric acid and acid phosphates. As soon as hardening occurs, this action would cease, as a result of the completion of the chemical reaction between powder and liquid. Consequently, any antiseptic property present from this source is of short duration, and permanent antiseptic power must evidently be derived from antiseptic substances placed in the cement with the idea that they will be liberated during the dissolution of the hardened cement. Thus it will be perceived that cements containing these substances will depend on the character and amount of them contained in their formula, and the rate of solubility of the cement. The liberation of these antiseptics will be relatively slower in cements of low solubility than in those of porous nature and rapid solubility.

As has been previously stated, so-called germicidal cements depend on the presence of germicidal salts of copper or silver for their antiseptic effect. Black and red copper cements, whose powder consists largely of copper salts (cupric oxid, black; cuprous oxid, red) have been reported by various investigators as being highly germicidal, some claiming that even spores are killed, while others deny their efficiency as spore destroyers. All copper germicidal salts produce discoloration, and black and red copper cements are highly undesirable in this respect. Zinc oxyphosphate cements containing small percentages of copper salts (copper iodides and silicates) are lighter in color and produce less discoloration, but are undoubtedly much less germicidal in power. The more soluble these cements are, the more quickly will the copper salts be liberated and the cement be dissolved and require replacing. For this reason, so-called copper cements with low percentages of copper (about 2%) are gradually coming into bad repute as germicidal cementing agents.

Although the so-called "silver germicidal cements" are highly expounded by their manufacturers, they possess the same shortcomings as the lastly mentioned preparations. They are zinc oxyphosphate cements containing about 2% of silver chlorid or silver phosphate as germicidal agents. They all produce discoloration and depend on their rapid solubility for elimination of the silver salt. C. Jane Fraser[8] attributes very high germicidal efficiency to one of these silver cements under the conditions in which the laboratory experiments were conducted, but unless the permanency of these products can be improved, they will undoubtedly be relegated to the same status as the light copper cements. Hill and Boester[9] have shown that the addition of 1 part in 5000, or 1 part in 10,000 of phenylmercuric nitrate to the regular zinc oxyphosphate cement base produces a cement comparable in its germicidal properties to any commercial germicidal cement and that the germicidal property is vastly more diffusible in agar than with cements which depend on the salts of copper and silver for their germicidal efficiency.

PULP IRRITATION UNDER CEMENTS

The literature of the profession contains many references to the causes of pulp irritation, degeneration and death under cement fillings. The silicate cements have been mentioned as the chief offenders in this respect, and the use of a non-conductive varnish is recommended by the manufacturers to protect the pulp against the action of these products. Fig. 486.

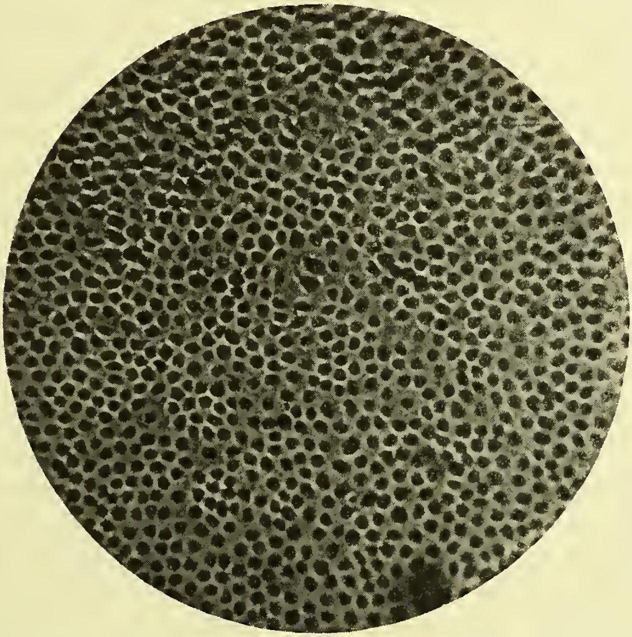


FIG. 486.—Cross section of dentinal tubules, seen from the pulp chamber. High power. (Courtesy of Dr. John B. Stein.)

The chief causes mentioned for pulp irritation following the introduction of dental cement into cavities are (1) acidity of the cement, (2) pressure in introduction against thin dentinal walls overlying the pulp, (3) infection from improper cavity preparation and sterilization, (4) heat generated from improper mixing, and (5) arsenic as an impurity.

1. **Acidity.**—There is a possibility of temporary irritation of the pulp from excess phosphoric acid of the liquid, if very thin, improper mixes have been made, especially if the tooth has been strongly desiccated, or if the cavity is very deep. On account of the danger of absorption

into the dentinal tubules of excess phosphoric acid before setting of the cement too much desiccation should be avoided and the cement should not be mixed too thin. If properly mixed and the above precautions observed, there can be no possibility of this occurring after setting, with either the oxyphosphates or the silicates. Walter S. Crowell[10] found the pH value of all the modern dental cements slightly above that of saliva, which indicates that they are less acid than the medium in which they are bathed. The silicates he found slightly more acid than the oxyphosphates, but still less acid than normal saliva which pH value as given by D. E. Starr averages 6.6. The presence of slight traces of fluorin in silicate cements is, according to Crowell,[11] not dangerous, since it is in an insoluble form and can not be transformed into hydrofluoric acid. He also states that even if it could be, it would be in so dilute a form and in such small amounts that it would be harmless.

2. Expansion and Pressure.—Irritation from these causes could occur only over very thin walls of cavities closely approaching the pulp. With proper mixes and the correct use of the better grades of cements, its occurrence would be improbable. Marked expansion of a poor grade, incorrectly mixed oxyphosphate or silicate, held tightly in position by a matrix until set, might occasionally produce it. This should be borne in mind and proper precautions observed to avoid it through careful mixes, use of cements which do not expand excessively, exclusion of moisture and avoidance of too much pressure in deep seated cavities.

3. Infection.—Undoubtedly, infection of the pulp from leaving traces of carious dentin or debris, or improper sterilization of deep cavities before insertion of the cement, would account for many cases of pulp irritation reported. This would occur under any type of filling material and should not, of course, be attributed to the action of the cement used.

4. Heat Generation.—Heat is generated in all chemical reactions, including the mixing of cements. It occurs more rapidly in quick setting cements and in cements mixed carelessly and too quickly. With proper mixes and with slow setting cements, the same amount of heat is generated, but its elimination is distributed over a longer period and thus a lower temperature is reached. Rapid generation of heat through careless and too rapid mixes will undoubtedly produce a thermal shock to the pulp, which may result in inflammation and death. Fig. 487. Temperatures above 140°F. are painful to the hand and, if transmitted to the pulp would produce thermal shock, which might result in grave consequences. The use of cavity linings, avoidance of cements which generate heat excessively, and proper mixes will eliminate this danger.

Experiments have demonstrated that some cements, improperly mixed, will generate a temperature as high as 165°F. Those setting with proper mixing above 120°F. should be considered dangerous. Setting temperatures may be easily determined by placing the mix in a gelatin capsule and inserting a clinical thermometer into the mix. A simple method of determining heat elimination is to apply on a small wood applicator some of the mix to the lip of the operator. If excessive heat is felt, thermal shock to the pulp would be likely.

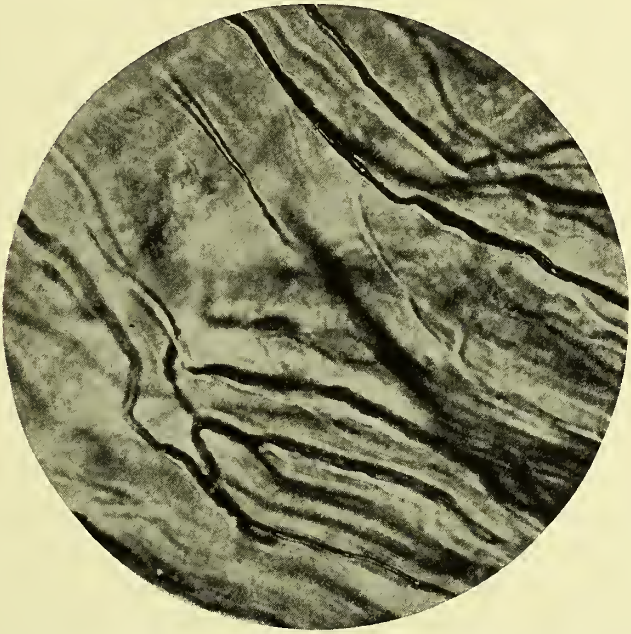


Fig. 487.—Dentin showing convoluted tubules. (Courtesy of Dr. John B. Stein.)

5. **Arsenic.**—The arsenic limit referred to under the heading "General Properties of Cements" precludes arsenic in accepted dental cements as a cause of pulp death.

MIXING CEMENTS

The Chemical Reaction.—No matter how carefully and scientifically prepared the liquid and powder may be, the final result to be obtained with cements depends on the method of mixing and insertion used by the dentist. This final stage in cement making rests with the operator. Manipulation has a definite effect on heat production, granularity, porosity, solubility, stability of from, adhesiveness, adaptability to cavity walls, permeability by moisture and micro-organisms, and crushing resistance.

The initial chemical reaction resulting with zinc oxyphosphate, when powder and liquid are mixed may be expressed as $ZnO + H_3Po_4 +$ water $= ZnHPo_4.3H_2O +$ water. It is thus perceived that the presence of water is necessary as a component. The $ZnHPo_4.3H_2O$ (zinc acid phosphate trihydrate) is precipitated in a finely divided state. As the setting reaction progresses, increasing amounts of the salts are precipitated until all the liquid has been absorbed. The plastic mass is thus gradually transformed into a hard cement, consisting of spherical aggregates of branching crystallites, firmly binding together particles of powder. Somewhat similar reactions occur in many copper oxyphosphates. The setting of both of these types of cements is a crystallizing process and the breaking up of the crystal aggregate does not permanently prevent proper crystallization of the mass. As previously mentioned, the silicates set by gelation of silicic acid. Silicic acid gel, if broken, does not again unite properly. Any interference during the gelation or hardening process will permanently destroy the continuity of the mass, the lasting qualities and translucence of the finished filling. In view of these facts, the mixing of silicate cements must be continuous and the material must not be disturbed after setting begins.

GENERAL DIRECTIONS FOR MIXING

Owing to variations in chemical composition and resultant working properties, only general directions can be given for mixing cements. Specific instructions for each type of product are furnished by the manufacturer and should be closely followed. Use a clean, broad, highly polished glass slab about 3 × 6 × 1 inches in dimension. Fig. 488. Separate slabs should be used for the different types of cement. They should be kept scrupulously clean and free from remnants of former mixes, grease, dirt or other impurities. The slab should be washed with alcohol and chilled to about 65 degrees temperature immediately before use, to avoid heat production. A heavy, wide, stiff-bladed spatula of tantalum, tarno, stellite, or agate, scrupulously clean is indicated for spatulation. Separate spatulas should be used for different cements. Steel or German silver spatulas are contra-indicated, on account of chemical action of the liquid on these metals.

Care should be taken to avoid contamination of powder and liquid, by keeping them tightly stoppered when not in use, by pouring out the powder and using a pipette or glass rod for dropping the liquid. The amount of powder and liquid to be used will be regulated according to the size of the cavity or restoration to be made.

Mixing Oxyphosphates.—The manufacturers of the dental cements conforming to the American Dental Association specifications supply accurate instructions for proportioning and manipulating their product. These instructions include the temperature of the slab, the powder: liquid ratio, the rate of powder incorporation and the time of mixing.

The following are the general directions for mixing oxyphosphate cements. The powder should be placed near the far end of the slab and divided into four or five portions. The liquid is placed near the other end, when, after closing the bottles, the mix is begun by drawing into the liquid about one-fourth the total amount of powder. The mix must be continued uninterruptedly, adding additional amounts of powder until the desired consistency is obtained. Never add liquid to the mix, since this would interfere with proper crystallization or hardening. The mixing should be thoroughly performed and without haste. Careless and incomplete or hasty mixing will result in the production of too much heat, porosity, expansion, too rapid setting and failure. The first portion of the powder drawn in should be thoroughly spatulated until every grain of powder is incorporated. The completeness of this first mix is highly important, since incomplete incorporation will be very difficult to correct later. Never leave unmixed portions of powder in any part of the mass. Spatulation should be accomplished with a rotary motion, spreading the mix out thin on the slab and covering all portions of it with the movements of the spatula. Then scrape the mix together and spatulate again, continuing until smoothness is noted and felt under the spatula, when additional small portions of powder are successively drawn in and spatulated as before, until the desired consistency is reached.

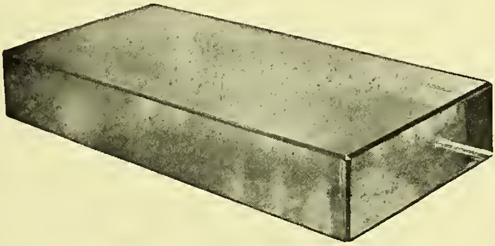


FIG. 488.—Glass slab for mixing cement.

The oxyphosphates are mixed to the consistency of thick cream for cementing inlays, bands, crowns and bridges; for filling work, to about the consistency of putty. The proper consistency for this type of cement is determined by collecting the mass on the end of the spatula and allowing it to drop to the slab. If it drops off slowly in a thick creamy mass and holds its drop form for a moment before spreading, it has been mixed correctly for cementation purposes. For fillings, additional powder should be added until the mass is still sticky and when collected on the spatula will not drop from it, but will remain and retain its spherical form. The time required for the mix varies from one and one-half to two and one-half minutes, depending on the consistency desired and the brand of product used. A sand-glass on the mixing table is a convenient means of timing

CAVITY PREPARATION FOR CEMENT

The same care should be observed in the preparation of the cavity as for other materials, if the best results are to be attained. All decay should be removed, slight retentive form should be obtained and the enamel margins should be highly polished, but beveled as little as conditions will permit. Absolute dryness is essential during cavity preparation, insertion and polishing of the cement, and the rubber dam is indicated for this purpose. The dentin should not be too strongly desiccated, else there will be a tendency to absorption into the tubules of liquid from the plastic cement, with consequent tendency to pulp irritation. A cavity varnish may be used, if deemed desirable.

INSERTION OF THE FILLING

Insertion of the filling should begin promptly on completion of the mix. Pack in small portions, with smooth burnishers, first into the angles, then against the lateral walls, thoroughly condensing with as much force as the material will allow, by means of smooth burnishers. Fig. 489. In very deep cavities, too much force should be avoided, on

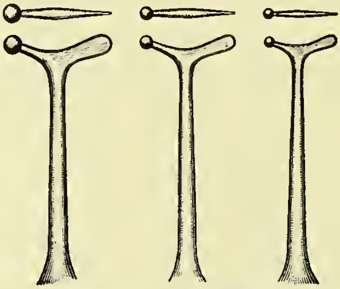


Fig. 489.—Burnishers.

account of the danger of pulp irritation from pressure over thin dentinal walls. Complete the insertion by filling the cavity to a slight excess and molding to anatomical form; then allow it to harden thoroughly before removing excess and polishing. Trim and polish with knives, smooth discs and strips, after which the rubber dam may be removed.

TECHNIC FOR SILICATE CEMENTS

The technic for manipulation of the silicate cements varies, depending on the product used. The instructions given under the heading entitled "General Directions for Mixing" apply to all cements. The finer details of mixing and insertion of silicates must be obtained from the literature of the manufacturers of the various products. A few additional general instructions, however, may be given, which will apply to the manipulation of all silicates.

The selection and blending of proper shades to match the various tooth colors is extremely important and requires close study, long experience and the possession of an "eye for color." Shade guides, color blending guides and directions are furnished by the various manufacturers to assist in selection and blending. The color and blends necessary should be determined before the dam is applied and while the tooth is bathed in saliva. On matching colors, do not raise the lip too high or have the mouth of the patient too wide. Thus will the normal shadow of the lip and of the oral cavity be cast on the labial and lingual surfaces of the tooth to be matched. Also, it is well to stand directly in front of the patient, because a side view will present different lighting and color values. A fresh mix of silicate is lighter in color than after it has set for some time, and although it may be a perfect match when introduced, it may be too dark after a few days. Owing to the shadow thrown by the proximating tooth, a shade slightly lighter in color will often be better for Class III cavities, while for Class V cavities, the finished filling had better be a trifle dark than too light.

The Mix.—1. Use a clean agate spatula for mixing and clean tarno, stellite or tantalum instruments for insertion. Fig. 490.

2. Sterilize the cavity, dry thoroughly, avoiding too much desiccation, and apply a cavity varnish, being careful to see that the margins are free from varnish before insertion of the filling.

3. Do not return excess powder left on the slab to the bottle, else contamination of the contents of the bottle may occur.

4. Keep the liquid bottle clean, the neck and cap dry and free from crystals.

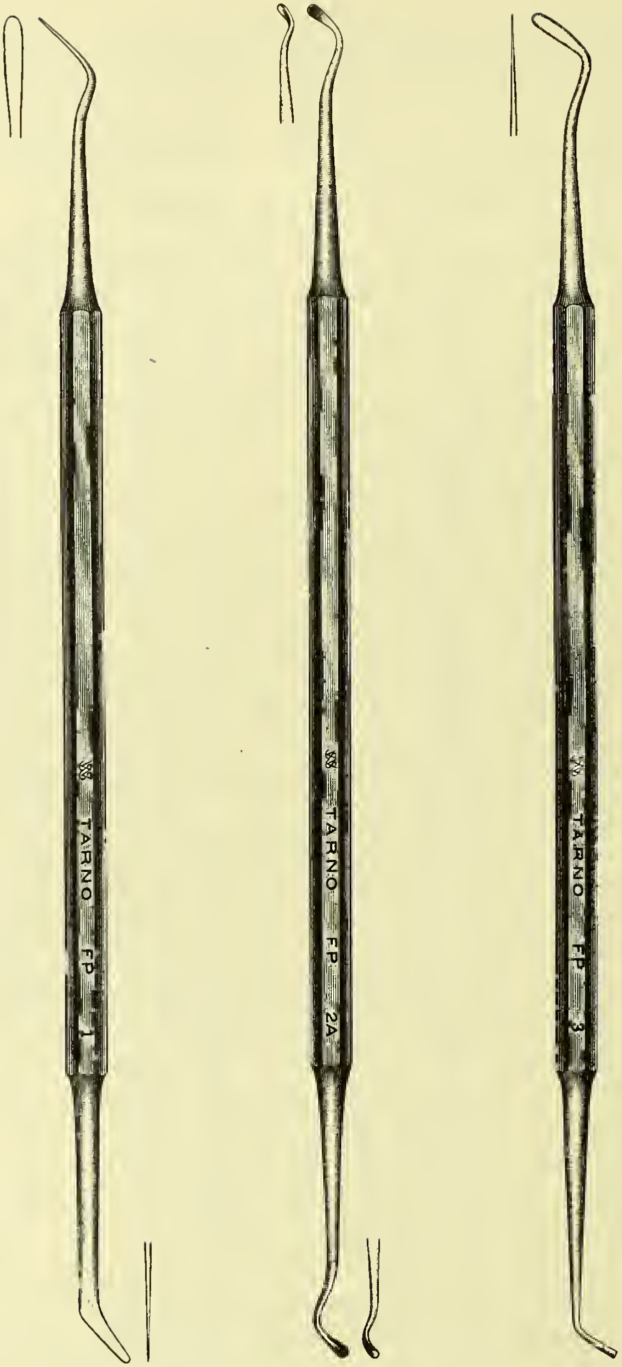


FIG. 490.—Tarno silicate porcelain filling instruments.

5. Expel the liquid from the pipette several times, holding the pipette deeply in the bottle, before taking up liquid for use.

6. Do not place liquid or powder on the slab until everything is in readiness for the mix.

7. For proximal cavities, use a clean celluloid strip as a matrix. Do not anoint the strip with cocoa-butter. The strip should be about .003 inch in thickness for attainment of the best results.

8. Do not spread the mix over the slab or resort to excessive spatulation. The great chemical affinity of the liquid and powder makes immoderate spatulation not only unnecessary but a disadvantage. This may interfere with proper gelation.

9. The mix should be timed with a sand glass or watch and occupy not over one minute to one minute and a quarter, depending on temperature, humidity, and the product used.

10. Divide the powder into halves and the second half into thirds. Then draw in the larger portion and mix thoroughly over a small area, holding the spatula flat. Next draw in the first small portion of powder and spatulate, when the mix should be of about the consistency of vaseline. Next draw in the second small portion and spatulate as before, when the mix should assume a putty-like condition. Now draw the mix together, lay the spatula upon it and raise the spatula, when, if the mix follows the spatula, it is too thin. If this is the case, add more powder from the last small portion until the mix, when spread under the spatula, "roughs up" and presents a broken or fluffy surface; or on repeating the above test, the mix does not follow the spatula. Now, if, on patting the assembled mix twice with the spatula, moisture arises to the surface, the mix is of proper consistency and should be inserted immediately into the cavity.

Insertion and Polishing.—1. Insert the material as quickly and with as little manipulation as conditions will permit, to avoid interference with the gelation process.

2. Apply it in small portions, first into the angles, then against lateral walls and then fill the cavity to a slight excess.

3. In proximal cavities, trim and fit the celluloid matrix before making the mix. Adapt it carefully to position with the idea of avoiding excess material on gingival and lingual margins. Now make the mix, insert the material and then draw the celluloid strip over the filling, being careful it does not slip and pull the silicate away from a margin. Do not use cocoa-butter on the strip.

4. Hold the celluloid matrix to place with light pressure for three minutes. Do not burnish it to place, on account of the danger of disturbing the gelation process. For removal, do not lift it, on account of the danger of disturbing the margins before the material has hardened, but push it toward the filling, when, if it does not release its grip on the material, hold in position for another minute and then carefully remove in the manner indicated.

5. To exclude the air, coat the filling with cocoa-butter immediately after insertion into cavities not requiring a matrix, or immediately after removal of the matrix, when the latter is used, and allow the material to harden undisturbed for ten to fifteen minutes.

6. Do not use a hot instrument to apply cocoa-butter, and avoid the use of heat in any form to hasten setting.

7. At the expiration of ten or fifteen minutes, any gross excess of material which would interfere with occlusion may be carefully removed with fine small stones or discs lubricated with cocoa-butter, following which the cocoa-butter should be swabbed off with dry cotton and the surface of the filling coated with the varnish supplied by the manufacturer for this purpose.

8. Now dry the varnish thoroughly with cold air, split the dam and carefully remove it, avoiding disturbing the varnish on account of the danger of entrance of air or moisture.

9. Dismiss the patient for 36 to 48 hours, at the expiration of which time setting is complete and the filling may be polished.

10. Polish with fine-cut, true-running, small stones, discs and strips anointed with cocoa-butter, avoiding heat from friction and damaging the margins.

Bibliography

1. Crowell, Walter S.: Physical chemistry of dental cements, Jour. Amer. Dent. Assoc., June 1927, p. 103.
2. Ward, Marcus L.: "American Text-book of Operative Dentistry," 6th ed., p. 526.
3. Ames, W. V. B.: Dental Review, 1914.
4. Poetschke, Paul: Germicidal efficiency of dental cements, Dental Cosmos, vol. LVIII, March 1916, p. 325.
5. Smirnow, M. R.: Germicidal properties of dental cements, Dental Cosmos, vol. LVII, Oct. 1915, pp. 1209–1228.
6. Bacon, Raymond F.: Germicidal efficiency of copper cements, Dental Cosmos, vol. LVIII, Jan. 1916, p. 40.
7. Fraser, C. Jane: Study of efficiency of dental fillings, Jour. Dental Research, vol. IX, no. 4, Aug. 1929.
8. Fraser, C. Jane: Study of efficiency of dental fillings, Jour. Dental Research, vol. IX, no. 4, Aug. 1929.

9. Hill, Thos. J. and Boesten, Karl W.: Relative efficiency of germicidal cement, Jr. A.D.A. vol. 21, page 1565 (1934).
10. Crowell, Walter S.: Physical chemistry of dental cements, Jour. Amer. Dent. Assoc., June 1927, p. 103.
11. Crowell, Walter S.: Physical chemistry of dental cements, Jour. Amer. Dent. Assoc., June 1927, p. 1030.

Diamond, M.: Dental Anatomy—A graphic representation of crown forms with technic for their reproduction, Jour. Amer. Dent. Assoc., March 1930, p. 470.

Prime, James Mark: Dental physiology, Jour. Amer. Dent. Assoc., Oct. 1929, p. 1850.

Paffenbarger, Sweeney and Isaacs: Preliminary Report of Zinc Phosphate Cements, Jr. A.D.A. vol. 20, p. 1960.

Paffenbarger, Sweeney and Isaacs: Zinc Phosphate Cements: Physical Properties and a specification, Jr. A.D.A. vol. 21, p. 1907.

CHAPTER XVII

RESTORATIVE OPERATIONS BY MEANS OF AMALGAM—PHYSICAL AND METALLURGICAL PROPERTIES—METHOD OF MANIPULATION

Introduction.—In the previous chapter the properties, methods of manufacture and manipulation of the temporary filling materials were discussed. We are now concerned with a similar consideration of the permanent materials at present available for restoration of tooth structure by means of the filling operation. The materials to be discussed are amalgam and gold, the use of tin for this purpose being almost obsolete. In this chapter amalgam is considered.

AMALGAM

An amalgam is a mixture or union of mercury with one or more other metals. Most modern dental amalgams consist of a combination of mercury with silver, tin, copper, and zinc. The word amalgam is of Greek origin, being derived from *malagma* from *malasso*, meaning to soften, the melting point of the mixture being lowered and the mass being thus softened by the presence of mercury.

An alloy is a union of two or more metals by means of heat. The term is derived from the Latin, *alligare*, meaning to combine. This is a definition of a dental alloy only, as some metals may also be combined into an alloy by electrodeposition and others by pressure at ordinary temperatures. These latter methods are not used in the manufacture of dental alloys. In the union of the constituents of an amalgam, the mixture may be either (*a*) a chemical compound; (*b*) a solidified solution of one metal in another; (*c*) a mechanical mixture; or (*d*) a combination of all three methods of union. Mercury has the physical property of dissolving other metals, in the same manner that water dissolves saline substances, alcohol dissolves resins, or ether dissolves fats. What takes place in the union is the lowering of the fusing points of the alloyed metals, by the introduction of mercury. A plastic stage ensues, which is quickly followed by crystallization and hardening. The advantage of alloying metals consists in the fact that a new compound is formed, which possesses a number of properties which are not inherent in a single element. Certain desirable qualities possessed by one metal are thus retained, while its undesirable properties are counteracted by the influence of the other metals in the combination.

Dental alloys, when mixed with mercury, are likely to possess one or more of the following properties, which are imparted to the mass by qualities inherent in the constituents, or by methods of manipulation, viz., (1) flow, (2) shrinkage, (3) expansion.

Flow.—Many metals, when subjected to constant or frequently repeated, intermittent stress, as from the stress of mastication, or movement of the contact points against each other, possess the tendency to slowly move from under the stress, thus gradually changing their shape. Some, notably tin, possess more of this property than others. The U. S. Bureau of Standards has fixed 4% as the maximum flow allowable during the twenty-four hours following condensation, in its tests for acceptable amalgams.

Shrinkage and Expansion.—Some metals, when heated or amalgamated (mixed with mercury), shrink, while others expand. The ideal amalgam is one in which the constituents are so combined as to possess neither of the above qualities to any great degree, permanent shrinkage being entirely absent. All modern, scientifically-constructed amalgams, if properly worked, possess the quality of slight ultimate expansion. Cheap grades, or poorly-manipulated products may exhibit the opposite quality, or ultimate shrinkage on hardening. According to recent tests of the U. S. Bureau of Standards, a dimensional change on setting value of 3 to 13 microns per centimeter (0.03 to 0.13%) is allowable.

Spheroiding—The spheroiding of amalgam has been much discussed in the literature. By spheroiding was meant the supposed tendency to become round, imparted to the mass by the mercury. A form of spheroiding undoubtedly occurs with amalgams which have been mixed too soft, leaving an excess of mercury, and producing a "sloppy mix." Dr. Black[1] called attention to this, stating that "when a very soft, sloppy amalgam is forced into a sharp angle, the mass will slightly *withdraw from the angle immediately the pressure is removed.* This it will do so long as it is soft, no matter how often it is forced close into the angle. And when the filling is removed from the matrix after hardening, all such angles will be found round instead of sharp." This may be prevented by avoiding soft, sloppy mixes, using proper proportions of mercury and alloy and expressing remaining excess mercury during the mixing and the packing.

So-called spheroiding, occurring after setting of the filling is associated with flow and undue expansion, the amalgam bulging up in the only free direction, viz., on the surface. This is largely prevented by using high percentage, properly balanced modern alloys and by properly mixing and adapting them into the cavity.

The advantages and disadvantages of Amalgam as a filling material are as follows:

Advantages

First.—High crushing resistance.

Second.—Insolubility in the fluids of the mouth.

Third.—Convenience of manipulation.

Fourth.—Adaptibility to cavity walls.

Fifth.—Capability of polish.

Disadvantages

First.—Inharmonious color.

Second.—Tendency to molecular change, viz., flow, expansion, shrinkage.

Third.—Lack of edge strength when built to thin edges.

Fourth.—High conductivity.

METALLURGICAL PROPERTIES OF SILVER, TIN, COPPER, AND ZINC

The various metals in dental alloys possess certain properties, some of which they import to the mass, when combined with mercury. Some desirable qualities of one metal overcome undesirable ones of another in the combination, if the metals are combined in the correct proportions. The chief properties of the constituents of dental alloys are as follows:

Silver (1) It unites with mercury only fairly readily in definite atomic proportions. (2) It tarnishes from the action of sulfids in the mouth. (3) It expands. (4) It retards setting of the mass. (5) It increases edge strength. (6) It lessens flow; and (7) It amalgamates slowly and with difficulty.

Tin (1) It unites readily with mercury in all proportions; (2) Retards setting; (3) Increases flow; (4) Imparts plasticity to the mass; (5) Shrinks; and (6) Decreases edge strength.

Copper (1) It unites with mercury with difficulty in definite atomic proportions; (2) It hastens setting; (3) Increases edge strength; (4) Lessens flow; (5) Shows no appreciable expansion or contraction; and (6) It tarnishes readily in the presence of hydrogen sulfid and soluble sulfids.

Zinc (1) It unites easily with mercury in definite atomic proportions; (2) It expands; (3) Hastens setting; (4) Diminishes edge strength; (5) Increases flow; (6) Improves the color of the mass; and (7) Imparts plasticity.

CLASSIFICATION OF AMALGAMS

Amalgams may be classified according to the number of constituents they contain into:

First.—Binary Amalgams—Those containing mercury and one other metal. Example, copper amalgam.

Second.—Ternary Amalgams—Those containing mercury and two other metals. Example, Townsend's Amalgam, containing mercury, silver, and tin. This preparation is now obsolete.

Third.—Quaternary Amalgams—Those containing mercury and three other metals, (so-called Black's Amalgams). Example, mercury, silver, tin, and copper.

Fourth.—Quinary Amalgams—Those containing mercury and four other metals. Example, mercury, silver, tin, copper, and zinc. Most of the acceptable amalgams in use today are quinary amalgams.

CLASSIFICATION AND GENERAL FORMULAS OF DENTAL ALLOYS

First.—High percentage or quick-setting alloys.

Formula: Silver, 64 to 65%; Tin, 25%; Copper, 3 to 6%; Zinc (in some) ½ to 2%.

Second.—Low percentage, slow-setting or plastic alloys.

Formula: Silver, 43 to 48%; Tin. 48 to 58%; Zinc, 1 to 2%. These alloys are now practically discarded for filling purposes, since they do not meet the demands of modern dental practice.

The properties characteristic of quick-setting or high-percentage alloys are rapidity of setting, comparatively low plasticity, high crushing resistance and edge strength, stability of form (minimum of shrinkage, expansion and flow). These alloys are sometimes designated as Dr. Black's alloys, but they are wrongly named, as they do not always follow his formulas. In contra-distinction the properties of slow-setting, low-percentage or plastic alloys are slowness of setting, lightness of color, plasticity (easy working), low crushing resistance and edge strength, great tendency to shrinkage, expansion and flow, and requirement of little mercury to amalgamate.

Dr. G. V. Black's opinion in regard to the incorporation of copper, zinc, gold, platinum and other metals into alloys was that the addition of not more than 5% copper increases strength without injury in other ways, and is desirable; that zinc is inadmissible, on account of its tendency to produce change in bulk, and that no advantage is derived from the addition of gold or platinum.

In his experiments he found that the alloy exhibiting least shrinkage and expansion was composed of Silver 72.5%; Tin 27.5%. Modern dental alloys are based on a modification of this formula by the addition of copper and zinc, to add certain desirable properties.

Dental alloys were formerly tested for shrinkage, expansion and crushing strength by mixing with mercury, packing in a Wedelstaedt or Wedelstaedt-Ward steel test tube, removing and submitting them to the specific gravity test; or by measuring them with Black's, Ward's or Crandall's amalgam micrometer, used in connection with a microscope and a dynamometer. These methods are now considered obsolete and more delicate tests are used, as specified by the U. S. Bureau of Standards.

The factors influencing contraction and expansion of alloys are,

First.—Composition of the alloy. The constituents must be properly balanced and free from impurities.

Second.—Manner of melting, casting and cooling during its manufacture. It is necessary that these procedures be carefully conducted by the manufacturer to produce definite results.

Third.—Kind of cut of the alloy (granules or shavings). Granules are considered better and usually combine more readily with mercury.

Fourth.—Amount of annealing during its manufacture. Temperature and length of annealing time are important.

Fifth.—Percentage of mercury used in amalgamation and manipulation by the dentist.

Sixth.—Manner of mixing alloy and mercury, and packing—also under control of the dentist.

Modern dental alloys are made by melting the metals in a closed electric crucible in an atmosphere of hydrogen. After cooling, the resultant ingot is filed into granules, or pared into shavings, the granules being considered the better form. The process of cutting produces hardening of the alloy similar to the condition produced by hammering the same metals. If the cut alloy were allowed to stand for a long time before using, this would remedy the hardening thus produced, with the result that it would become soft. By properly heating or annealing the mass, the same softening effect is produced as that accomplished by aging. Freshly-cut alloy has entirely different properties from aged or annealed alloy, hence the necessity for proper annealing by the manufacturer. The act of annealing alloys produces the following results:

First.—It reduces the tendency to expansion or contraction.

Second.—It retards setting.

Third.—It facilitates amalgamation.

Fourth.—It reduces the percentage of mercury required.

Fifth.—It increases crushing resistance and tensile strength.

As marketed by the manufacturer, a dental alloy is supposed to possess the qualities as regards setting, expansion, edge strength, etc.; which it is intended it should have. If improperly annealed, these qualities change with age. This being the case, high grade alloys are at present very carefully annealed. However, to prevent any tendency to deterioration, an alloy should not be kept near a heater, in the sun, or in an overheated room. It should be kept in a cool, dry place to prevent any possibility of additional aging.

Discoloration.—The formation of sulfids, through the action of hydrogen sulfid from putrefactive decomposition of foods in the mouth, on silver or copper in the amalgam, is likely to produce discoloration of tooth structure. Fruit acids, acids of wines and of fermentation (foods) also produce colored salts with copper, which are likely to be absorbed into the dentinal tubules and produce similar results. Discoloration of tooth structure does not occur to any extent unless leakage and disintegration of the filling supervenes.

Strength.—The strength of amalgam depends on the composition of the alloy, the method of manufacture, and the manner of mixing and packing. The manufacturer must produce a perfectly balanced alloy and the dentist must properly manipulate it, if desirable results are to be obtained in this regard. A balanced alloy is one so constituted that shrinkage is prevented, expansion is controlled within definite limits, crushing resistance is adequate, and flow is nominal.

Copper amalgam occasionally is useful for filling purposes. This material is an amalgamation of pure copper and mercury, consequently a binary amalgam. It is produced by the manufacturer after one of two methods, viz.:

First Method.—Add freshly precipitated and washed metallic copper to an excess of mercury; express the excess of mercury by wringing in chamois; pack into moulds and allow to harden, when it is dispensed ready for use.

Second Method.—Precipitate copper into mercury by electrolysis.

Copper amalgam is prepared for introduction into the cavity by heating one of the tablets in a special spoon made for that purpose, crushing and grinding in a mortar, and then manipulating as other amalgams. The properties usually attributed to copper amalgam are as follows:

First.—It is antiseptic, due to the formation of copper sulfate, thus supposedly acting as a tooth preservative.

Second.—It produces marked tooth discoloration and turns black.

Third.—It possesses great crushing resistance.

Fourth.—It has stability of form; no shrinkage, expansion practically nil.

Fifth.—It imparts a metallic taste in some mouths.

Sixth.—It causes voltaic disturbances, occasionally.

Seventh.—It disintegrates in some mouths, due to the formation of carbonates and sulfids.

Owing to the tendency to disintegrate, copper amalgam fillings will, more readily than those of silver-tin content show, in time, leakage and permeability to water. Their germicidal effect is undoubtedly due in a measure to the tendency to disintegrate, thus liberating germicidal copper salts. To prevent leakage, they may be covered with a layer of amalgam of high-silver content. This procedure, however, would largely prevent liberation of the copper salts necessary for its germicidal effect and consequently lower its efficiency in this respect. For these reasons, copper amalgam must be regarded as of doubtful utility, except in unusual cases requiring it, as in the mouths of children, where proper access, removal of decay, absolute exclusion of moisture and adequate cavity preparations are difficult.

HISTORY OF THE DEVELOPMENT OF AMALGAM AS A FILLING MATERIAL

The first dental silver amalgam is supposed to have been introduced by Bell of England in 1819 and later used by Taveau in Paris in 1826.

Dr. D. M. Cattell[2] is responsible for the statement that the first dental amalgam was introduced into this country by the Crawcour brothers under the name of "Royal Mineral Succedaneum," in 1833. Dr. Black states that the precise date and the first person who used amalgam in dentistry are uncertain. Before its introduction non-cohesive gold and tin were the materials used for filling teeth.

In the beginning, many dentists made amalgam by filing silver coins and mixing the filings with mercury. This produced a harsh mass, which was difficult to mix, hardened very slowly and changed form enormously. These qualities soon brought it into ill repute, and those who used it were classed as quacks and charlatans. However, some began a study of it in an attempt to improve it. This lead to the addition of tin to the silver, which was accomplished by rubbing tin foil with the silver filings, thus breaking it up into fine masses which united with the mercury. This produced a more plastic mass, which set more rapidly and amalgamated much easier. Later an alloy of silver and tin was made by melting the metals, which was a marked improvement over the previous plan of mixing the metals in a cold state.

While these developments were occurring, there was very strong opposition to the use of amalgam by the better practitioners, which finally resulted in a crusade against its use. Thus was the "amalgam war" initiated in 1841, which lasted many years.

Dr. Chapin A. Harris in his opening address to the first class of the Baltimore College of Dental Surgery, founded in 1839 as the first dental college, said of amalgam that "it is one of the most abominable articles for filling teeth that could be employed." Many cases were reported of systemic effects and even death resulting from the presence of mercury in the amalgam. Patients were sent to dentists by physicians with instructions to remove all amalgam fillings and the Onondaga Medical Society of New York adopted resolutions to the effect that the use of amalgam produced depression, nervousness, indigestion, ptyalism, paralysis, and death. In 1843 a resolution was passed by the American Society of Dental Surgeons, the first organized dental society in America, declaring the use of amalgam as malpractice. In 1845 the "amalgam pledge" was adopted by this organization. This was a pledge not to use amalgam, and forced expulsion of all members who refused to sign it. A number were expelled for this cause. This pledge was rescinded in 1850, which marked the official end of the "amalgam war," although marked opposition to its use continued for many years by prominent members of the profession. Later, investigations of amalgam formulas for determination of shrinkage, expansion and other properties were carried out in the United States, Germany, and France. The first of these was conducted by John Tomes of London and reported in the Transactions of the Odontological Society of Great Britain in 1861. Thomas Fletcher of Warrington, England, later conducted similar tests, and in 1871 Charles Tomes of England tested various amalgams for shrinkage and expansion by means of the specific gravity test. Kirby in 1871 and 1872 reported similar tests in the Transactions of the Odontological Society of Great Britain and later Adolph Witzel and other

German investigators reported the results of their experiments. In 1874 important work was reported by Dr. Thomas Hitchcock in the Transactions of the New York Odontological Society. He suggested plans of study by which more accurate data might be obtained through the use of a micrometer. Dr. J. Foster Flagg, a prominent American dentist, was always a strong champion of amalgam and contributed many articles, largely of a clinical nature, in its defense. He headed what was known as the "New Departure" group. Flagg's alloys are still in the market, but do not now meet modern ideas as to composition or working properties. Up to this time most investigations reported tended to show that the various amalgams in use, with the exception of copper amalgam, showed either marked contraction or expansion, and this was the situation which confronted Dr. G. V. Black when he initiated a systematic and scientific study of the problems involved, in 1895.

DR. BLACK'S RESEARCHES ON AMALGAM

When Dr. Black began his investigations, he found, after reviewing the work of all previous laborers in this field, that many different formulas had been tried and found wanting. Silver alone, used for amalgamation had been shown by many men to expand, while silver-tin mixtures had been shown to contract. However, Dr. Black at once recognized that, other metals having been tried and proven untrustworthy, a compound of silver and tin must serve as the basis for the development of a satisfactory dental amalgam. A brief review of his work follows:

1. He designed a special micrometer, capable of making measurements of 1/10,000 of an inch, for testing bulk changes of various combinations of metals; a dynamometer and also a binocular microscope for following up and proving the work of the micrometer. In tests made for expansion and contraction with these instruments, he used a steel test tube designed by Dr. E. K. Wedelstaedt, into which the amalgam was packed.

2. With these instruments, he found after a long series of tests that (1) it was necessary to melt the metals composing the alloy in an atmosphere of hydrogen in a closed electric crucible, to produce proper union; (2) that an annealed alloy of silver 72.5% and tin 27.5% was perfectly balanced and exhibited with his measuring devices no expansion or contraction; (3) that metals, when freshly cut, were hard and gradually became soft with age, as a result of which "aging" they changed their molecular relationships, and exhibited different properties from freshly cut alloys; (4) that the balanced silver-tin alloy was not sufficiently hard

to resist high crushing stresses and it was necessary to modify it by the addition of about 5% copper for this purpose; (5) that the addition of zinc produced change of form in time and was inadvisable; (6) that exact formulas were not practicable, owing to the difficulty of obtaining at that time pure metals; but (7) that volume changes could be eliminated, sufficient strength obtained and all other desirable attributes could be produced by proper methods of production by the manufacturer and of manipulation by the dentist.

3. Dr. Black also investigated the possibility of improving the color of amalgams and decided that the addition for this purpose of zinc or any of the noble metals, such as gold or platinum, was inadmissable, since they produced change of form and other undesirable properties. Also, he reported that discoloration of the surface of amalgam fillings was due to the formation of sulfids from putrefaction, from fruit acids, acids of wines and of fermentation. He stated that (1) discoloration of dentin could not occur unless moisture, carrying coloring agents or germs entered as a result of change of form of the filling, or from recurring decay; (2) that dentinal tubules containing vital tissue resisted the entrance of coloring agents, while dentin cut off from its sources of nutrition during the preparation of the cavity readily absorbed them; and (3) that the so-called "black ditch" seen around amalgam fillings was due to change of form, lack of proper adaptation or recurrence of decay, allowing coloring agents, germs and food debris to enter. A full discussion of these matters, as well as his findings in regard to strength, flow, so-called spheroiding, and methods of manipulation was published in the Dental Cosmos in 1895, 1896, and in other Journals in succeeding years. A comprehensive review is contained in the second volume of his work on Operative Dentistry.

This outstanding work of Black served as a basis for later researches with improved instruments and technic by such men as Marcus L. Ward,[3] Arthur W. Grey,[4] W. G. Crandal,[5] C. M. McCauley,[6] William E. Harper,[7] and others.

EXPERIMENTAL WORK OF ARTHUR W. GREY

In 1919 with more delicate measuring machines Grey[8] determined among other things the following important details:

1. Changes in dimensions can be altered at will by varying the proportions of alloy and mercury in the mix, the time of mixing and the pressure used in packing.

2. The age of the properly annealed alloy has no effect on its stability of form.

3. Prolongation of the time of mixing is likely to leave an excess of mercury in the mass, which, however, can be removed by heavy packing pressures. The time of trituration should not exceed three minutes, on account of the difficulty of rapidly applying the packing pressure by hand.

4. The time of adaptation of the filling should not exceed two minutes to obtain the best results.

5. Amalgam made from high silver percentage alloy, if subjected to sudden crushing stress presented adequate and high resistance to this type of stress, but when excessive stresses were applied, it burst explosively, owing to its brittleness.

CONTRIBUTIONS OF MARCUS L. WARD

Dr. Ward[9] has made many valuable contributions to our present knowledge of dental amalgams as well as in other fields. In reviewing the work of Black and Grey, he became convinced that the reported tests for crushing resistance and flow were inadequate and did not sufficiently indicate the resistance of amalgam to various forms of crushing and compression stresses, tensile, shearing and impact forces. In 1924, through modifications of an Olsen Universal Testing machine, briquettes and cylinders of amalgam of high silver content were tested for compression and tensile resistance to both sudden and slowly increasing loads. An improved machine was devised to make tests for shearing, and a standard Olsen machine was used for the impact tests. This work is reported in the June 1924 issue of the Journal of the American Dental Association and in the sixth edition of the American Text-book of Operative Dentistry.

Dr. Ward found that if the load were applied rapidly the cylinders would crush explosively on the application of 2,100 to 2,500 pounds stress. Subjection of similar size cylinders to a slowly and gradually increased stress, extending from twenty to twenty-five minutes resulted in explosive crushing at approximately 1,650 pounds. When a similar load was applied over a period of about one hour the cylinder would bend and flow into an irregular form, but would not crush, thus exhibiting flow under this type of stress. On application of the shearing test, it was found that the cylinder could be sheared apart at about 125 pounds pressure, while the impact test revealed the fact that amalgam, if hit quickly from one side could be broken with an impact of from 1½ to 3 inch pounds, an amount equivalent to that required for producing similar results on good quality of glass or porcelain. As a result of these experiments, attention was called to the fact that the crushing resistance of amalgam varies with the type of force applied, depending on whether in the form of a sudden or gradual direct compression, whether it is of a tensile or shearing nature, or whether in the nature of a lateral impact. Consequently, Dr. Ward stressed the importance of providing adequate resistance and retention form in the proximal portion and also of allowing for sufficient body of amalgam in the step portion of Class II cavities, to resist not only ordinary crushing stresses, but tensile, shearing and lateral impacts. Thus it is perceived that the "strength" of amalgam involves many considerations.

CONTRIBUTIONS OF DR. WILLIAM E. HARPER

Dr. Harper[10] has contributed numerous articles to the Journals, tending to improve the technic of manipulation of amalgam. An early and important one appeared in the Journal of the American Dental Association in December 1919 and was followed by others in the Journal of Dental Research and other publications. He perfected an apparatus for testing the resistance of amalgam fillings to air pressure. With this machine, he has reported that 90% of amalgam fillings examined by him, as ordinarily inserted, leaked under an air pressure of 4 pounds applied from within on completion of the filling. Of the remaining 10%, many leaked under air pressure of 3 pounds at the expiration of 9 months. Forty per cent of these fillings showed defects large enough to be apparent to the eye immediately after completion, and he claims that since these leaks occurred almost immediately, they were the result of faults of manipulation, producing shrinkage and expansion of the amalgam.

Also Dr. Harper states[11] that "amalgam is a typical eutectic mixture alloy in which one of the components is a comparatively high-fusing, strong and stable chemical compound, Ag_3Hg_4, the granules of which, in the finished filling, will be embedded to a dangerous degree in a soft, low-fusing eutectic matrix of tin and mercury, unless we very thoroughly and forcefully express the soft eutectic during the packing." Further, he stresses the difference between a *workable* plasticity (present for five or six minutes during the mix) and an *adaptable* plasticity (present for only two or three minutes during the time allowed for adaptation), with quick setting alloys. In view of the importance of the removal of the soft eutectic and the limited time available to accomplish this and to produce perfect adaptation to cavity walls, he has repeatedly stressed in his articles what he considers the prime factors to be observed in perfecting a proper technic. These factors are correct proportions of alloy and mercury, correct time desirable for making the mix and adapting the filling, decided plasticity of the mix, tamping to position, packing under a stress of 9 to 16 pounds and orderly condensation.

WORK AT THE BUREAU OF STANDARDS

The Bureau of Standards of the U. S. Department of Commerce has reported valuable researches on dental materials, some of which are still in progress. This work was originally undertaken in 1919 at the request of the War Department for an investigation of dental amalgam. In 1922, a cooperative research with the Weinstein Research Laboratories was established and continued for about six years. In this latter research an investigation of wrought and cast golds, solders, waxes and investments was conducted. In 1928 a cooperative research with the Research Commission of the American Dental Association was undertaken, which is still in progress. The purposes of these studies were to establish more perfect methods of testing dental materials, to determine the important properties of representative products in the market and to develop improvements in formulas and in the method of manipulation, based on the findings made. As a result of these investigations, much valuable information has been gained. These researches have been reported chiefly in Technological Paper number 157 of the Bureau, entitled "An investigation of the physical properties of dental materials," which deals with the findings on silver-tin alloys and which was reprinted in the Dental Cosmos, vol. LXII, March 1920, page 305; Federal Specifications Board, Specification number 345 (dental amalgam specification) which was reprinted in the Journal of Dental Research, vol. VII, June 1927, page 173; and Research Paper Number 32, entitled "Physical Properties of Dental Materials," which reports the findings on gold alloys and accessory materials. Numerous other reports were made in the dental journals by Wilmer Souder,[12] R. L. Coleman,[13] Wm. H. Swanger,[14] C. G. Peters,[15] N. O. Taylor,[16] G. C. Paffenbarger, W. T. Sweeny, and other members of the staff of the Bureau. These articles, appearing at intervals in the Dental Cosmos, Journal of the American Dental Association, the Journal of Dental Research and other publications are all valuable contributions to the literature of the profession. As stated, these researches are still in progress and are being reported from time to time, showing the progress of this valuable work.

RESEARCH ON DENTAL AMALGAMS AT THE BUREAU OF STANDARDS

When these researches were started at the Bureau of Standards, it was found that the precision instruments of Black, Grey, and other previous investigators were not delicate enough to register the finer determinations necessary, consequently, they were discarded. Dimensional changes with temperature (thermal expansion) of tooth structure and filling materials were measured with an interferometer, capable of registering very minute displacements, which was connected with appliances to regulate the temperature, thermostats, thermometers, thermocouples, and other necessary adjuncts. Dimensional changes (contraction and expansion) of amalgam during the hardening or setting period were also recorded with the interferometer. A special micrometer, an improvement on the Black and other dynamometers, was used to measure flow, and the regular testing machine equipment of the Bureau was utilized in testing for crushing strength. A normal calomel half cell and potentiometer was used in measuring electrode potential determinations, and the chemical compositions of the prominent dental alloys obtained on the open market were determined by the chemical apparatus of the Bureau, through qualitative and quantitative analysis.

The following findings were reported through the medium of the aforementioned publications:

Thermal Expansion.—The experiments were made with the interferometer on samples of the various materials 6 mm. in diameter by 1 cm. long. They were subjected to temperatures ranging from 5°C. to 120°C. The coefficient of linear thermal expansion is the elongation of unit length per degree rise of temperature. A temperature range of about 50°C. was decided upon as a fair representation of the temperature variations to which the teeth and metallic fillings are usually subjected, the temperature of cracked ice and ice water being approximately 5°C. and of hot foods and drinks 50 to 60°C.

The table on p. 480 represents the findings of the Bureau as to thermal expansion. An examination of this table reveals that the thermal expansion of teeth shows an average value of approximately 8, the crown expansion being 11.4. Silicate porcelain averages 7.5, gold 14.4, amalgam about 25, while guttapercha shows an average range of 198.3. Most of the samples exhibited irregular reactions near 80°C., showing a slight contraction and then a rapid expansion above that temperature, with exudation of soft drops of mercury. Amalgam fillings, if subject to this temperature would undoubtedly suffer serious injury.

Effects resulting from difference in expansion of the teeth and various filling materials will depend on the temperature range, size of the cavity and elasticity of the tooth and material used. For example, the case of a cavity and filling 1 cm. in diameter undergoing a temperature variation of 50°C. is cited in the report in Technologic Paper number 157 of the Bureau. The free expansion along each coordinate axis is 4 microns for the cavity, 7 microns for a gold filling and 12.5 microns for an amalgam filling. If the dimension or temperature range is less, the effect will be reduced proportionately. If there is a perfect adaptation of the filling to the cavity walls and no stress at the lower tempera-

AVERAGE EXPANSION COEFFICIENTS. RANGE 20° TO 50°C.

Material	Expansion. Coeff. × 10^6
Tooth (root)	8.3
Tooth (across crown)	11.4
Tooth (root and crown)	6.4
Tooth (root and crown)	8.7
Tooth (root and crown)	8.3
Silicate porcelain	7.1
Silicate porcelain	8.1
Silicate porcelain	7.5
Amalgam H	26.4
C	25.0
K	22.1
P	24.5
A	25.4
B	28.0
L	24.8
C	25.0
C	24.7
C	28.0
Porcelain (Bayeux)	4.1
Gold	14.4
Platinum	9.0
Silver	19.2
Mercury (linear)	60.6
Zinc	29.2
Tin	22.3
Copper	16.8
Guttapercha	198.3
Aluminum	23.1
Steel	11.0

Explanatory Note:—The expansions are tabulated as the amount of expansion, in microns, for a specimen 1 m. in length, when heated 1°C., e.g., amalgam C will change 25 microns per meter per degree; or, in terms of a specimen 1 cm. long (the approximate diameter of a molar) the expansion is 0.25 micron per degree = 2.5 microns per 10 degree range = 12.5 microns per 50 degree range, etc.

ture, then at the higher temperature there are, quoting from the aforementioned report, two possibilities: "(1) The elasticity of the tooth and compressibility of the filling may be such that perfect adaptation is maintained or (2) the rigidity of the tooth and plasticity of the material may be such that there will be a flow of material in the only free direction, causing a spheroiding or bulging over the cavity. With a perfectly rigid tooth cavity, this may equal three times the linear differential expansion of the substances, which will be 25 microns in the case of amalgams. Should the filling material take a permanent set at the higher temperature, then on returning to the lower temperature, all materials having undergone free contraction, there is a possibility of a 4 micron separation around the filling." These examples very well illustrate the bearing of differences in thermal expansions of tooth structure and filling materials and of perfection of adaptation to cavity walls on the question of permanence of results.

Dimensional Changes During Setting.—The amount of expansion and contraction of many dental amalgams in the market was determined by means of the interferometer. The specimens were amalgamated and condensed into moulds 1 cm. long. The results obtained from varying the temperature during the setting period from 8 to 37°C. demonstrated that temperature control was not of the importance previously emphasized by Grey in his experiments. Most of the samples hardened in a few minutes, but a number of the low silver alloys were still quite soft after 60 minutes. Annealing of the alloys at 120°C. for three hours showed very little difference in the results obtained, indicating that proper annealing had previously been practiced by the manufacturers. The addition of 1⅔% zinc to one alloy increased its total contraction. Prolonged mulling (mixing) demonstrated that marked contraction changes, 10 to 20 microns per centimeter, could be produced with any of the amalgams and that slight irregularities due to variations in room temperature were insignificant in comparison.

Most of the samples showed initial contraction of from 1 to 3 microns during the first 30 or 40 minutes, after which they expanded in various amounts for about 400 minutes and then remained constant during the rest of the experiment. With some samples the initial contraction continued and no recovery was evidenced. Experiments lead to the conclusion that 1 or 2 microns of this initial contraction was due to thermal contraction of the material incident to manipulation in the hand, the remainder being attributed to real contraction due to natural properties and proportions of the constituents. All of the experiments proved that heat is evolved during amalgamation and continues throughout the period when variations of length occur. The heat evolved kept the temperature of the sample above that of the surroundings for several hours.

These experiments indicated that there was great variation in the volume changes of the various amalgams; that most of the high percentage silver-tin alloys exhibited an initial contraction, followed by expansion in varying degrees; that the time of mulling was very important, that heat was evolved during amalgamation and that zinc was productive of increased contraction.

Crushing Strength and Flow under Compression.—It was found through use of the special micrometer that all amalgams flow under constant pressure for months after amalgamation and that the questions of flow and crushing strength are relative factors. When the load is applied suddenly, the crushing strength runs high. When applied continuously, it is greatly diminished. Most of the amalgams tested after 48 hours, exhibited crushing strength over 32,000 pounds per square inch if crushed quickly, usually in about 3 minutes. Some of them exhibited crushing strengths when tested after 14 days of over 45,000 pounds per square inch, two crushing suddenly at 49,500 pounds pressure. One of the latter was a non-zinc alloy; the other contained 1% zinc. By mechanically packing the specimen under very high pressure immediately after amalgamation, it was found that it was possible to almost double the crushing resistance, thus demonstrating the importance of the use of high pressure in packing.

In the flow tests, made after 48 hours, with the special micrometer and weight pan, it was demonstrated that one-tenth of the load, 3,200 pounds, maintained constantly would produce crushing with many of the specimens after 20 hours. One amalgam subjected to the flow test under 3,200 pounds two hours after amalgamation was compressed over 40% in thirty minutes. The same amalgam tested in a similar manner after 48 hours was compressed 18% and fractured after 3 days. Another quick setting amalgam showed a flow of over 10% after 1,200 minutes when the test was begun 2 hours after amalgamation. Many of the amalgams tested exhibited much less tendency to flow than the cases just mentioned. The qualities producing failures are attributed to chemical composition of the alloy, and stress is laid on the importance of low percentage of flow on maintenance of the integrity of contact points, margins and occlusal form. Smallness of the area of proximal or occlusal contact has the effect of intensifying the impacts. During service the material is being constantly subjected to stresses similar to those incident to hammering the head of a rivet, where light blows will in time flatten its head.

TABLE 3.—COMPARISON OF AMALGAMS

Alloy		Crushing strength in pounds per square inch	Per cent flow in 24 hours	Relative blackening	Setting changes, first 24 hours (all values in microns per centimeter)			Claims
Mark	Partial composition				Maximum contraction	Maximum expansion	Final state	
A	Ag 68....... Zn 0........	49,500 51,550	4.4	7 ...	1.5 ...	5.6 ...	+ 4.3 + 4.5 + 2.2	A correct material certified as to balance
B	Ag 67....... Zn 2........	46,500 40,300	3.1	1 ...	3.9 ...	1.5 ...	+ .5 − 1.7 − .2	It is balanced, produces a white amalgam of great strength, free from slightest contraction, has a slight initial expansion never exceeding 3/10,000 inch, takes a high polish
C	Ag 68....... Zn 1........	39,800 38,200 44,200	4.0	0	.6	6.7	+ 5.2 + 6.7 + 4.9	Made in accordance with the investigations of Dr. G. V. Black; is a balanced alloy. This is a perfect alloy in every respect, is age proof, an exact alloy, highest crushing strength, is the only chemically clean alloy made
D	Ag 66....... Zn (1)......	39,950 35,550	3.4	0 ...	.8 ...	5.5 ...	+ 2.1 + 2.6 + 3.7	
E	Ag 60....... Zn ( )......	41,950 38,900	9.1	4 ...	9.2 ...	.0 ...	− 6.8 − 5.7 − 5.0	White alloy
F	Ag 66....... Zn 1........	49,500 48,400	10.4+	2 ...	27.1 ...	.0 ...	−27.1 −21.3 −20.2	A balanced alloy made after the approved formula of G. V. Black, M. D., D. D. S.
G	Ag 68....... Zn ½.......	47,250 46,650	5.0	4 ...	3.5 ...	1.7 ...	+ .4 − .3 − 1.4	Never changes color, contraction nil, expansion 1/20,000
H	Ag 67....... Zn 1........	40,750 40,750	3.7	1 ...	4.1 ...	4.3 ...	+ 3.8 + 3.5 + .7	Used by the U. S. Navy, made after the Black formula.
I	Ag 68....... Zn ⅔.......	38,700 37,100	4.3	1 ...	7.7 ...	.0 ...	− 7.5 − 6.5	Does not shrink, about 1/20,000 expansion takes place; a perfect, nonleaking amalgam can be the only result
	Ag 67....... Zn 1........	42,750 44,800	7.8	8 ...	1.2 ...	3.8 ...	+ 2.5 + 2.4 + 2.5	A balanced alloy, permanent whiteness, made by the Black method, contraction nil, expansion 1/20,000
K	Ag 54....... Zn 0........	41,550 48,450	9.6	8 ...	2.4 ...	4.9 ...	+ 1.4 + 3.9 + 4.2	Depended upon not to shrink or change form; insures against stained teeth and gutters around fillings
L	Ag 54....... Zn 0........	33,600 38,700	5.3	4 ...	2.1 ...	3.2 ...	+ 2.6 + 3.0 + 2.1	Fillings do not shrink nor change form; has a fine white color which endures; can not shrink
M	Ag 54....... Zn ½.......	30,400 34,300 30,300	36.0	10	39.1	.0	−28.1	No shrinkage, no discoloration, a tooth saver; any higher price can not buy a better alloy; an honest, efficient filling material; takes a high polish and keeps it
N	Ag 45....... Zn 2........	30,850 38,500 30,000	47.1	7	7.8	.0	− 3.8	Nonshrinkage, nonexpansion, edge strength, retention of color
O	Ag 67....... Zn 1⅔......	40,750 34,000	2.5	2	1.9	.0	− 1.9	
P	Ag 60....... Zn 5........	41,200	2.6	1	7.2	.0	− 4.5	

Chemical Composition.—It was found that the chemical compositions varied from 45 to 69% silver and from 0 to 5% zinc, the other constituents consisting of copper and tin. Although the chemical formula is important, other factors were found to be very significant. An alloy triturated for 3 minutes gave 5 microns expansion in 24 hours, while the same alloy when triturated 30 minutes exhibited 15 microns contraction in the same time. Similar reactions were found for other alloys. Over-annealing for 2 hours in an electric oven at 120°C. produced little change in tendency to change form, although it made the amalgam more granular and produced slower setting. No very definite conclusions were reached in regard to the bearing of copper content on blackening, or of zinc content on volumetric change. A number of amalgams ranging from 0 to 5% zinc content were tested by means of a normal calomel half cell and potentiometer for electro-motive reaction. As a result, it was determined that little evidence was exhibited of excessive contact emf effects from the zinc content, and that the zinc was apparently in complete solution in the mercury.

Table 3, page 483, from Technologic Paper 157 shows a comparison of the more important characteristics found in an examination of 16 well-known alloys. The last column indicates the claims made by the manufacturers for these alloys and in many instances demonstrates that their claims were not substantiated by the tests of the Bureau.

As a result of these studies, a master specification for dental alloys was adopted, to which alloys to be used by the U. S. Government must conform. Changes have been made in this original specification and later approved by the Research Commission of the American Dental Association. A portion of the present specification is herewith given.

FEDERAL SPECIFICATION BOARD—SPECIFICATION NO. UA-451

AMERICAN DENTAL ASSOCIATION SPECIFICATION NO. 1 FOR DENTAL AMALGAM ALLOYS

I. Types—1. This specification is for the so-called "silver" amalgam alloys which are to be used for restorations in the mouth.

There are no general specifications applicable to this specification.

2. The alloy may be furnished as:

Type A. Shavings.

Type B. Filings.

II. Material

The comminuted alloy shall be free of foreign materials and shall be uniform and the amalgamated alloy shall not produce excessive blackening of the hand or white paper when rubbed against the hand or paper.

III. General Requirements

Amalgams shall possess the following features, known as satisfactory working qualities:

1. Thorough amalgamation in 3 minutes.
2. Absence of granular or sandy consistency when amalgamated.
3. Susceptibility to carving for at least 15 minutes after amalgamation.
4. Susceptibility to receiving and retaining a polish 24 hours after amalgamation.

IV. Detail Requirements

1. Chemical Composition—The chemical composition shall be within the following limits:

Silver	65% maximum
Tin	25% maximum
Copper	6% maximum
Zinc	2% maximum

Gold and platinum will not be regarded as foreign materials.

2. Flow—Specimens subjected to a constant pressure of 250 kilograms per square centimeter (approximately 3,550 pounds per square inch) shall not show more than 4% flow (i.e. more than 4% shortening in length of specimen) in a period of 24 hours.
3. Setting Changes—Twenty-four hours after amalgamation the length shall have increased between 3 and 13 microns per centimeter.

Note:—The complete specification is not included here. The remaining paragraphs more particularly concern the manufacturer.

Many important reports have been made before dental societies and in the Journals of findings by members of the staff of the Bureau. N. O. Taylor, research associate of the American Dental Association in the Bureau, reported the results of researches on the action of the various types of mechanical amalgamators now in use. This article appeared in the Journal of the American Dental Association, Vol. XVI, No. 4, April 1929, page 583 and showed conclusively that "mechanical amalgamation, in its present state of development and standardization, is both a doubtful and a dangerous method, and, until more definite data are available for the special type of amalgamation in question, should not be employed."

On page 590 of the same issue, Taylor reported other findings of importance. Two tables were presented, one showing the chemical composition of 28 prominent dental alloys and indicated that in 1928 only 15 of these complied with the requirements of the Federal specification in chemical composition. The other table indicated the results of tests on 29 alloys for contraction, expansion, flow, crushing strength, and other properties. Fig. 491. Only 6 of them complied with the requirements of the first master specification in this regard. This condition demonstrates that the majority of manufacturers had, up to that time, shown little evidence of an attempt to improve their products or to comply with modern demands for an acceptable alloy. However, in the report of the Bureau of Standards made at the annual meeting of the American Dental Association in Washington in October 1929, published in the Journal of the A. D. A. for January 1929, page 112, it was stated that at that time 18 alloys complied with the Federal specifications in all respects.

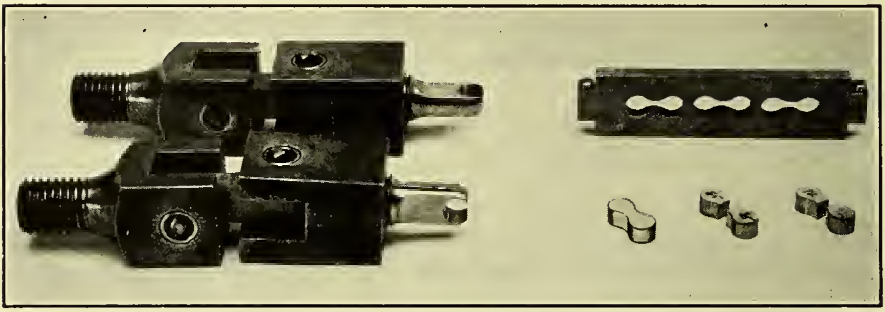


Fig. 491.—Molds, grips and samples as used in the determination of the tensile strength of amalgam alloys. (Courtesy of Dr. N. O. Taylor and the Journal of the American Dental Association.)

The revised list (page 487) of amalgam alloys as of June 1, 1935 was found to comply with the American Dental Association specification No. 1.

Systemic Poisoning from Mercury in Amalgams.—Attention was previously called to reports of systemic effects resulting from amalgam in the early history of its use as a filling material. A discussion of the supposed dangers arising from this cause has arisen intermittently since that time, but no scientific proofs have ever been advanced to substantiate the charges of these writers until recently. The subject has lately been revived in Germany, and a number of German writers have again called attention to local and systemic poisoning supposed to arise from the volatilization of mercury from amalgam fillings in the mouth. In 1927, Stock of the University of Berlin published a communication in which he drew attention to the alleged dangers. He claimed that under certain conditions, amalgam was dangerous to both patient and operator and that copper amalgam was especially so. In a later com-

Fourth Survey of Alloys

May 4, 1935
Revised November 1, 1935

Alloy	Manufacturer or Distributor
Accurate Metalloy (Filings)	The L. D. Caulk Co.
Ackerman (Filings)	Ackerman Dental Mfg. Co.
Argentum (Shavings)	Hammond Dental Mfg. Co.
Aristaloy	Baker & Co., Inc.
Banner (Filings)	Goldsmith Bros. S. & R. Co.
Blue Diamond (Filings)	Reliance Dental Mfg. Co.
Brewster Medium (Shavings)	E. R. S. Brewster
Brewster Quick (Filings)	E. R. S. Brewster
Brewster Quick (Shavings)	E. R. S. Brewster
Capeako (Filings)	Precious Metals Refining Works.
Certified	Lee S. Smith & Sons Mfg. Co.
Coe	Coe Laboratories, Inc.
Dee (Filings)	Thomas J. Dee & Co.
Excel	Daniels Dental Alloy Co.
Keystone	Lee S. Smith & Sons Mfg. Co.
Minimax (Filings) (Shavings)	The Minimax Co.
172 173	
173 177	
174 178	
177 180	
178 161	
180	
181	
183	
161	
Minimax White Gold & Platinum	The Minimax Co.
Mission No. 5	San Diego Smelting & Refining Co.
Modeloy (Quick Setting) (Filings)	Crescent Dental Mfg. Co.
Ney-Aloy	The J. M. Ney Co.
Odontographic "Improved" (Filings)	Odontographic Mfg. Co.
P.D.Q	Patterson-Hettinger Co.
Preferred D	Precious Metals Refining Works
Preferred C	Precious Metals Refining Works
Royal-Special First Setting	Garhart Dental Specialty Co.
Silverex	Interstate Dental Co., Inc.
Silverloy (Filings & Shavings)	Crescent Dental Mfg. Co.
Speyer	Speyer Smelting & Refining Co.
S-C Medium (Filings)	Stratford-Cookson Co.
S-C Quick (Filings)	Stratford-Cookson Co.
True Dentalloy (Filings)	S. S. White Dental Mfg. Co.
True Dentalloy (Cut A)	S. S. White Dental Mfg. Co.
Twentieth Century (Filings)	The L. D. Caulk Co.
White Beauty	Lang Dental Mfg. Co.

munication he admitted that there was very little danger from silver-tin amalgams. Müller in 1928 reported in the Deutsche Med. Wochenschrift a case of secondary anemia, with shortening of breath and edema of the ankles, which he attributed to mercury intoxication from a number of large copper amalgam fillings. He claimed that chemical examination of the stools showed the presence of mercury in small amounts and that evidence of electrolysis was marked, especially in one amalgam approximating a gold filling. These are examples of a renewal of the so-called "amalgam war" in Germany.

Many of the German investigators deny the possibility of deleterious effects from this cause, among whom are Schroder, Schroenbeck, Diek and Kitler, these latter maintaining that the small amount of mercury necessary to amalgamate the alloy could not develop sufficient mercurial vapor to give rise to appreciable disorder. Drigalski states that the examination of the urine of many patients carrying amalgam fillings failed to indicate the presence of mercury.

Mancardi of Italy reports the results of chemical and biologic researches which dispute the affirmative claims of Stock and other writers. He states that there may be some cases where many large copper amalgam fillings may do harm, but that silver amalgams are in no sense injurious. His of the Medical Clinic of Berlin claims that certain individuals are mercury carriers, although evidencing no signs of mercurial poisoning. In 36 persons examined carrying copper amalgam fillings, he reported that 30 disclosed the presence of mercury in the mouth and urine, but that only one out of 15 cases examined, carrying silver or gold amalgams, showed traces of it. Fleischman stated in a report of his investigations that the source of mercurial intoxication was due to inhalation of mercury by workers in occupations incident to the manufacture or handling of mercury and to absorption by patients wearing many large copper amalgam fillings. Mention of the reports of these findings is made in the Dental Cosmos, Vol. 69, Nov. 1927, p. 1205; Vol. 70, July 1928, p. 745; Journal A. M. A., July 30, 1927, and March 30, 1928.

There is now generally conceded to be no danger from mixing amalgam in the hand. Some dentists, however, have an idiosyncrasy toward mercury and such cases have been described in the literature. There is no danger to the patient from absorption of mercury from modern, scientifically constructed high percentage silver-tin alloys, properly amalgamated and manipulated, the chance of minute traces of mercury vapor being eliminated under the circumstances being nil. There is a possibility of deleterious effects resulting from the presence of many large copper amalgam fillings in a single mouth, owing to their tendency to rapidly disintegrate and eliminate mercury. It would seem, then, that the careless use of silver-tin alloys through "sloppy," improper mixes and imperfect condensation, leaving excess of mercury, is a danger which should be recognized, especially in poorly cared for mouths containing a large number of such type of fillings, with recurrent decay and infective processes. Also, that the danger of disturbances from excessive use of copper amalgam is another argument against its continuation as a filling material, except in rare instances, unless the copper amalgams now in use can be greatly improved in their lasting qualities.

AMERICAN DENTAL ASSOCIATION SPECIFICATION NO. 6 FOR DENTAL MERCURY

The following specification for dental mercury is suggested:

1. The mercury shall have a bright mirror-like surface free from any film or scum. Under certain conditions of storage, mercury may develop a slight film. Such mercury should readily be separated from this film by filtration through chamois skin or some similar filtering medium and, when filtered, should remain bright after agitation with air. It shall pour freely and in its entirety from a thoroughly clean glass container.

2. The mercury shall have a nonvolatile residue of not more than 0.02 per cent when the mercury is evaporated from a porcelain crucible at a temperature below its boiling point, and the crucible is then ignited at a dull red heat.

The proposed specification for purity was adopted as part of the American Dental Association's Specification No. 6, "Tentative Specification for Dental Mercury," Oct. 18, 1931. The following additional requirements are contained in the American Dental Association's Specification:

Methods of Inspection and Test: 1. The determination of nonvolatile residues shall be made on samples having a weight of from 10 to 15 gm.

Packing: 1. The minimum net weight of the contents shall be marked on each package. 2. Mercury shall be packed in clean clear glass containers.

Notes: 1. Guarantee. Manufacturers may indicate that their products comply with these requirements by placing a statement on the package guaranteeing the material contained therein to meet the requirements of this specification.

2. Responsibility for any Guarantee. All statements or guarantees that products meet this specification are made by the manufacturers on

their own responsibility. In the event of disagreement between purchaser and manufacturer, the American Dental Association will act in an advisory capacity and will designate testing laboratories having equipment for making necessary tests.

MERCURY

Certified Dental Mercury

A.D.A. Specification No. 6 as of January, 1932

Mercury	Manufacturer or Distributor
Argentum	Hammond Dental Mfg. Co.
Chemically Pure	S. S. White Dental Mfg. Co.
Dee	Thomas J. Dee & Co.
Dental	Goldsmith Bros. S. & R. Co.
Mercury Laboratories	Mercury Laboratories, Inc.
Minimax	The Minimax Co.
Mission	San Diego Smelting & Refining Co.
Ney's* C. P	The J. M. Ney Co.
Odontographic	Odontographic Mfg. Co.
Positively Pure	Garhart Dental Specialty Co.
R. P. C.	Research Products Corporation
Twentieth Century	The L. D. Caulk Co.

* This certificate does not apply to Ney's C. P. Mercury in one pound jugs, since the jugs are not glass.

MANIPULATION OF AMALGAM

In the previous pages we have discovered that the manufacture and manipulation of amalgam alloys is a complicated process and that the success of the completed filling depends on many factors.

The factors under the control of the manufacturers are:

1. Choice and purity of the constituents of the alloy.
2. Preparation of the constituents.
3. Method of melting, casting, cooling, cutting and annealing, all of which regulate expansion, shrinkage, stability of form, and crushing and other strengths.

The purity and proportion of constituents and the desirable properties are now specified by the Bureau of Standards and the American Dental Association. This indicates that the use of low percentage silver alloys is no longer admissable for filling purposes. Most of the manufacturers now are producing products which comply with the requirements of the Bureau of Standards and of the Research Commission of the American Dental Association. The factors under control of the dentist are:

1. Selection of a high-grade alloy, meeting the above specifications.
2. Proper cavity preparation and matrix application.

3. Correct ratio of mercury and alloy.
4. Time and method of mixing.
5. Method of adaptation and condensation into the cavity.
6. Removal of excess mercury during packing.
7. Carving and polishing the filling.

The manufacturers may produce the highest type of alloy possible, and yet failure of the filling may result from improper technical procedure on the part of the dentist. If improper mixes are made, imperfect adaptation and condensation produced, or excess mercury left in the filling, edge strength and crushing resistance are diminished, flow and volume form changes are increased, resulting in the formation of the "black ditch" around the filling, leakage, change of form, breakage, or loosening and failure. Thus it is seen that the quality of the finished product is in the hands of both manufacturer and operator, and that the latter controls to quite a large degree, in his manipulative procedures, those qualities necessary for success in amalgam work.

Cavity preparation for amalgam work varies very little from that for gold. The various steps, as previously described, should be carefully and conscientiously completed. Convenience angles are not necessary for starting the filling, the usual retention and resistance forms being all that are necessary. Owing to its lack of edge strength, the amount of bevel of the cavo-surface angle should be modified as much as conditions allow. Deeply buried bevels should be obtained wherever possible, in order to secure sufficient bulk of filling material at margins. Adequate bulk should also be provided for at the junction of the step with the proximal portion in Class II fillings. This may be accomplished by widening the step in that location and deepening it if deemed necessary. With proper seating this should prevent breaking away of the proximal from the occlusal part of the filling. Fig. 492.

The Matrix.—For filling with amalgam, the presence of four lateral walls to the cavity is a necessity, to prevent the squeezing out of the mass during the application of the great force required during the packing process. For this reason the use of the matrix is a necessity in proximo-occlusal cavities. Fig. 493. For a description of the matrix see Chapter XV.

Indications for Use.—Amalgam is contra-indicated in the front teeth. It may be used in pit and fissure cavities in occlusal, buccal and lingual surfaces of bicuspids and molars; proximal cavities of bicuspids and molars; gingival third cavities on buccal and lingual surfaces of bicuspids and molars. As a general rule it should be confined to locations obscured from view, even bicuspids, if possible. Frequently, small Class I cavities can easily and quickly be better filled with gold.

Washing Amalgams.—Sodium carbonate, dilute acids, ether, chloroform and alcohol have been used by some for washing amalgams before insertion into the cavity. They are all of doubtful value and may even do harm. The lightening of color produced is only temporary. Washing will loosen any metallic salts which have formed on the surface of the alloy from age, and allow the mercury to act more energetically, facilitating the mix, and hastening the setting; the time consumed in the washing, however, allows the mass to stiffen somewhat, which is a decided injury; in addition, some of the material used for washing may remain to a considerable extent as a foreign body, thus weakening the filling.

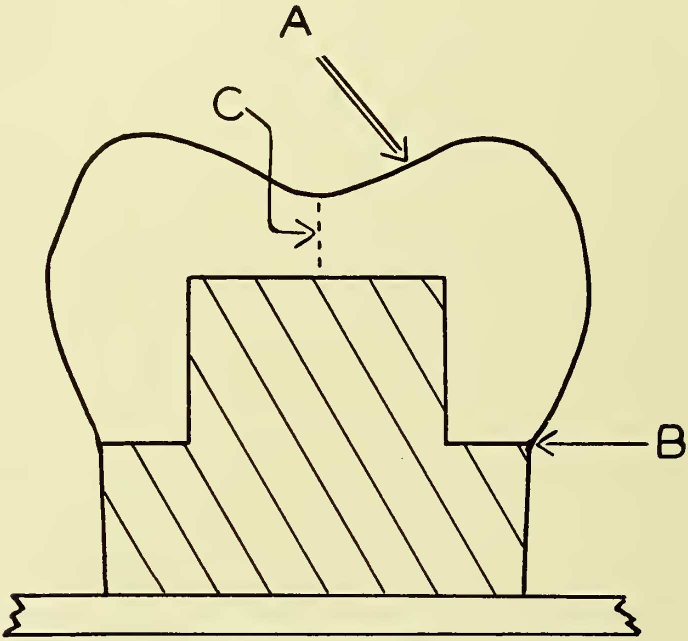


Fig. 492.—Tension in amalgam fillings. A force acting at A tends to rotate the filling at B., causing tension at C. (Courtesy of Dr. N. O. Taylor and The Journal of the American Dental Association.)

Pulp Protection.—In deep-seated and sensitive cavities, the wall overlying the pulp should be protected by means of a cavity lining and a layer of cement. This will prevent transmission of sensations to the pulp and also protect it from trauma incident to application of the force necessary to properly condense the filling. The elasticity of the dentin composing a thin cavity wall over a pulp should always be recognized and the danger of pressure avoided by proper pulp protection.

Making the Mix.—The method of mixing amalgams varies to some extent, depending on the type of alloy used. The proportion of mercury to the alloy varies in different formulas, and must be obtained by testing the batch, or from printed directions on the package. The average is about nine parts of alloy to eleven parts of mercury, by weight, although some alloys are marked five parts of alloy with seven parts mercury; four parts alloy with five parts mercury, etc. Ward[18] states that the average proportions are 1.6% mercury. Rapid-setting alloys usually require more mercury. To prevent change of form and to give the greatest edge strength, a part of the excess mercury must be removed in mixing and the balance during packing.

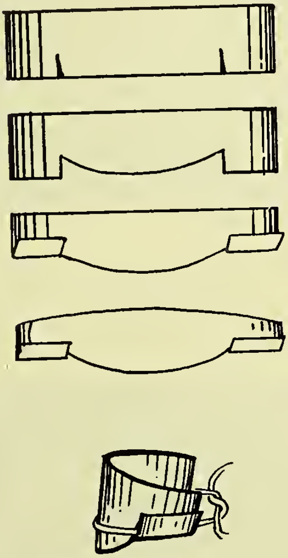


FIG. 493.—Steps in the construction of a copper matrix for amalgam fillings.

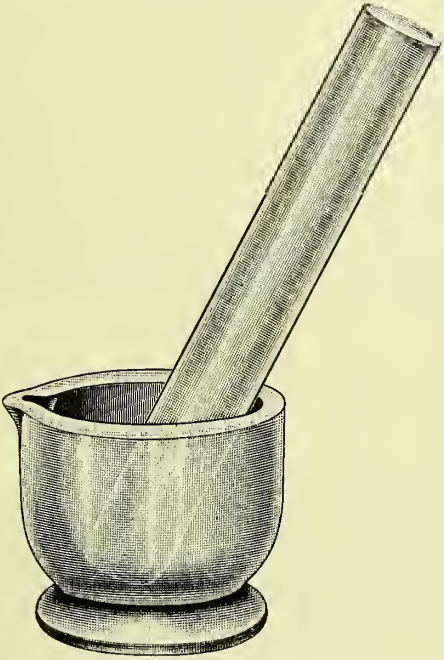
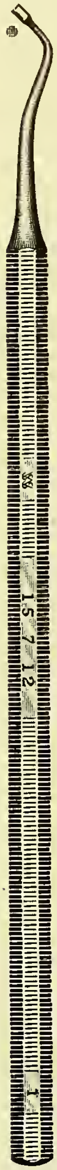


FIG. 494.—Glass mortar and pestle for mixing amalgam.

The mixing directions which now accompany the better grade alloys are designed to produce the optimum properties and should be followed.

The general directions for making the mix are. *First.*—Place the desired amount of alloy in a glass mortar and add the necessary amount of mercury by weight. Numerous forms of dispensing and weighing devices are available for this purpose. Fig. 494.

Second.—Mix thoroughly and forcibly with the pestle for two minutes until the alloy and mercury are completely incorporated.



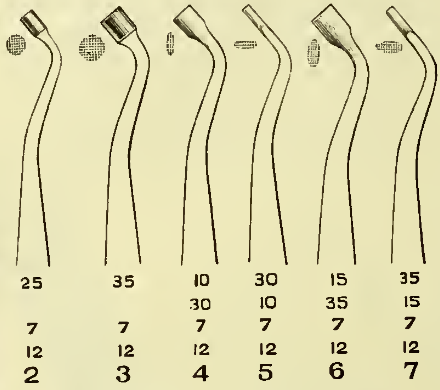


Fig. 495.—Black's amalgam pluggers.

Third.—Immediately remove to the dry, clean palm of the left hand and work vigorously, rapidly and continuously with the fingers of the right hand for one minute, squeezing frequently between thumb and forefinger and removing excess mercury. A sand glass or watch should be used for timing. The time should not exceed three minutes; for small mixes it may be reduced to two and one-half minutes. Mechanical amalgamators should be avoided.

Fourth.—Knead the amalgam until a fairly soft mass is obtained, having plasticity and bulk. Pack immediately into the cavity. The mass should not be allowed to lay still, or crystallization will begin.

Condensation.—The time should not exceed three minutes. For condensing the amalgam into the cavity, first cut the mass into several small pieces (depending on the size of the cavity) with a flat burnisher. The first piece used should be large enough to cover the floor of the cavity and should first be lightly tamped to place before packing pressure is applied. If desired, it may be carried to position with an all metal amalgam gun or carrier. Do not use too large pieces. Now tamp and then pack each piece separately with large serrated amalgam pluggers, Black's or Crandall's. Fig. 495. Do not use smooth burnishers. Pack with steady, forceful hand pressure, using all the force that the patient can comfortably tolerate and condensing thoroughly one piece at a time. The excess mercury should be expressed from each portion prior to insertion and by heavy condensation pressure. The amalgam surface to which portions are added should always be wet with mercury so that a strong union will be produced. Do not use tin-foil or gold-foil for removing excess, on account of the danger of forming a new alloy, possessing new properties. Pack the cavity overfull, first wringing the last portion dry between the folds of a mouth napkin or piece of chamois with flat-nosed pliers, to express any excess mercury. The hand mallet may be used with a large plugger, at the end of the packing process.

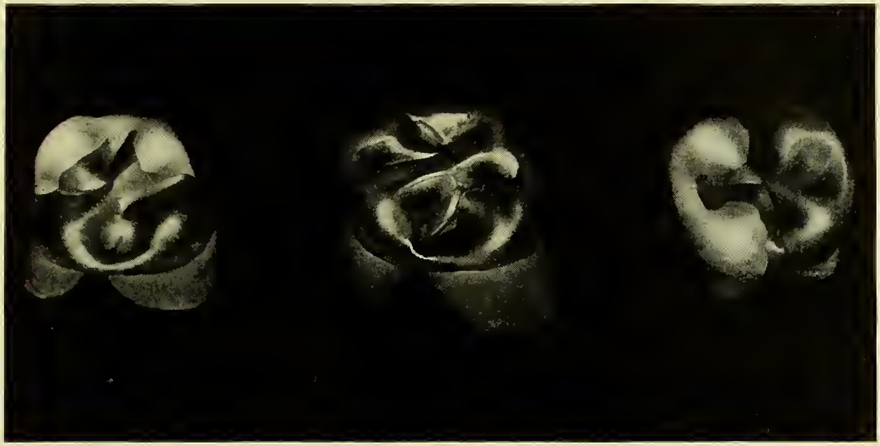


FIG. 496.—Amalgam fillings carved to anatomical form and polished.

Now allow the filling to set for several minutes before trimming and carving. Trim the excess with flat burnishers and knives or the Frahm, or Crandall carving instruments, toward the margins, leaving the filling carved to full contour on proximal surfaces, and to proper occlusal form on others. The final polishing is deferred for twenty-four, or better, forty-eight hours, to allow for complete setting.

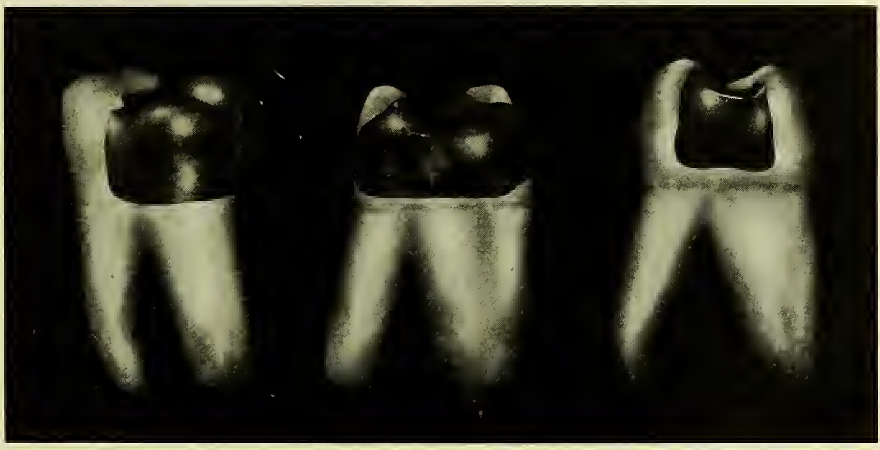


FIG. 497.—Amalgam fillings carved to anatomical form and polished.

Amalgam fillings should receive as thorough and careful polishing as gold. Figs. 496 and 497. It is impossible to do this except at a subsequent sitting. After careful burnishing, the patient should be dismissed for forty-eight hours when the final finishing and polishing should be performed. In Class II cavities with proper matrix application, separation and adequate condensation, the removal of the matrix will be likely to damage the filling unless carefully performed. After removal of the ligature, the thumb or finger should be placed on the filling to protect it, and the matrix band then carefully drawn out to the lingual side, using pliers for this purpose if necessary.

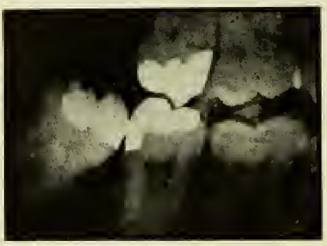


FIG. 498.—Three amalgam fillings. Good filling on lower second molar.

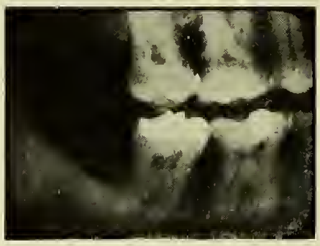


FIG. 499.—Well-finished filling in second molar.

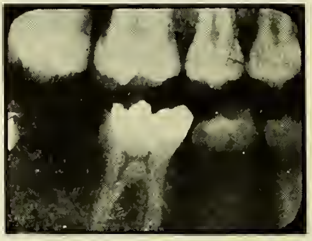


FIG. 500.—Amalgam filling. Pulp-capped.

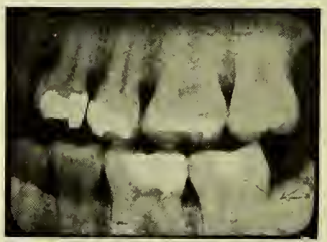


FIG. 501.—Splendid filling in lower first molar. Open contact between bicuspids.

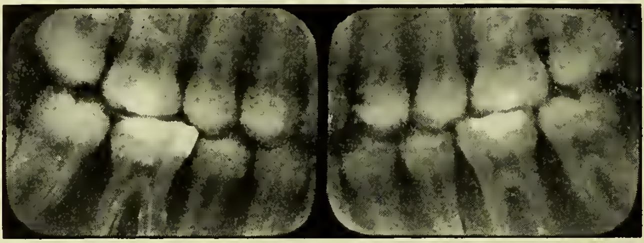


FIG. 502.—Four good fillings on upper and lower right and left first molars. Distal caries on lower right and left second bicuspids.

Carving and Polishing.—The importance of carving to anatomical form and proper occlusion already has been stressed. Figs. 498 to 502. In Class II cavities, carving of the occlusal portion should be completed before removal of the matrix. The marginal ridge should first be outlined, then the inclines of the cusps, and the fossae and grooves. Frahm carvers are valuable for this purpose. For deepening and further accentuating grooves and fossae, spoons, discoids, and gingival margin trimmers will bring out finer details of the work. After carving the occlusal surface, the matrix should be removed. Care should be observed

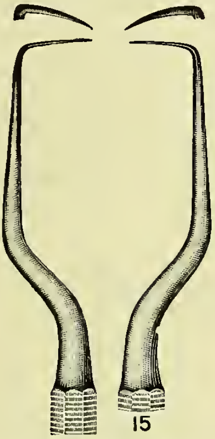


FIG. 503.—Prime finishing knives.

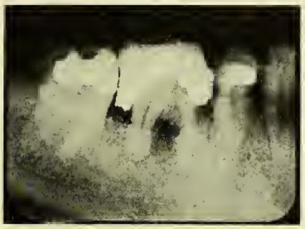


FIG. 504.—Mal-practice in filling with amalgam. Marked bone destruction.

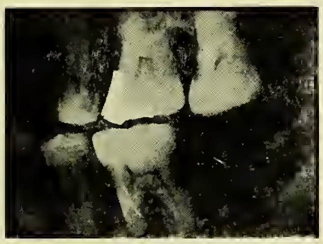


FIG. 505.—Poor adaptation and excess filling at gingival margin.

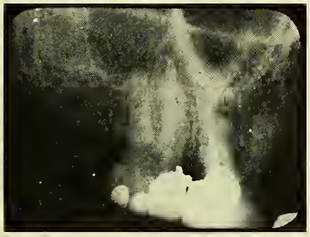


FIG. 506.—Mal-practice in restoration, showing destruction of interdental septa.

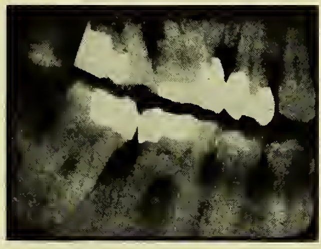


FIG. 507.—Fillings on upper and lower molars improperly finished at gingival margins.

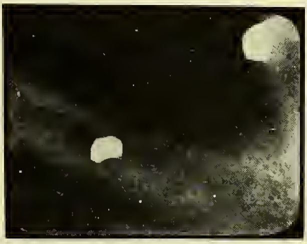


FIG. 508.—Part of old amalgam filling remaining in molar region.

in its removal not to flatten the contact point or to break the marginal ridge. Additional separation, if necessary, should be accomplished to avoid this. The proximal portion should now be trimmed and burnished to form with Black or Prime finishing knives (Fig. 503) and thin burnishers, removing all gingival and other overhang, and carving the proximal part of the marginal ridge to provide a proper spillway for food. Figs. 504 to 508. Avoid touching the contact point at this time. All carving and burnishing should be done with the rubber dam in position. This is now removed and the occlusion carefully tested by having the patient lightly close the jaws. If the filling has been carved too full, heavy stress is likely to damage it at this time. Any areas in which excessive stress is present, indicated by a small burnished facet from closure of the teeth, are removed, and the patient is then dismissed, with instructions to avoid pressure on the filling for several hours.

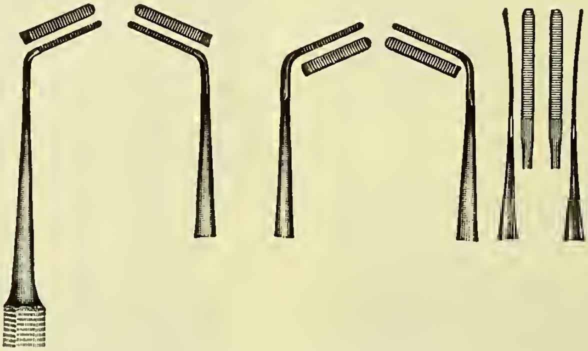


Fig. 509.—Prime's finishing files.

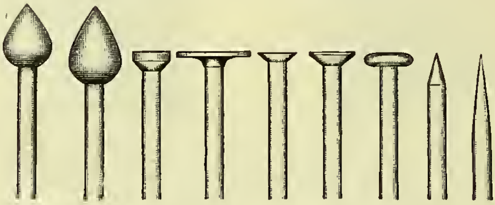


Fig. 510.—Wood polishing points and wheels for use in the engine.

At the next visit final polishing is completed. The proximal portion is first trimmed with the Black knives, Prime's finishing files, and proximal trimmers number 31 and 32. Fig. 509. Separation may be needed to avoid damaging the contact point. The gingival, buccal, and lingual portions may now be polished with fine polishing strips and discs, not bringing them over the contact point. The latter should now be lightly stripped with a very fine strip. The cusp inclines and marginal ridges of the occlusal surfaces are polished with wood wheels in the engine, carrying a paste of wet pumice flour. Fig. 510. The side, and not the edge of the wheel should be used, and every care observed not to polish out finer details of the previous carving. If the wood wheels are too large, they may be trimmed down by running them in the engine against a sharp knife blade. Grooves and fossae are now gone over with the flat side of sulci discs, being careful not to obliterate them by using too much pressure at the edge of the disc. Fig. 511. A fine polish is now given the entire filling with polishing brushes or chamois discs carrying tin oxid or whiting. Amalgam fillings, if examined after intervals of six months or a year often will be found to have changed form from flow or other bulk changes. For this reason, they should be frequently inspected and if the changes are observed, as evidenced by irregular margins, grinding down with fine stones, burnishing and polishing should be resorted to.

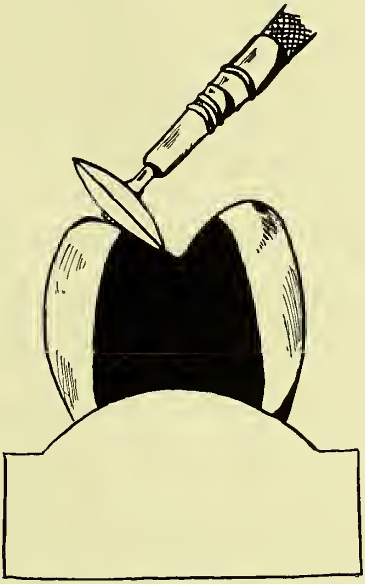


Fig. 511.—Use of a sulci disk for polishing grooves in the occlusal surface of a filling.

Bibliography

1. Black, G. V.: "Operative Dentistry," 6th ed., vol. 2, p. 317.
2. Cattell, D. M.: Pacific Dental Gazette, vol. 34, 1926, p. 186.
3. Ward, Marcus L.: Comparative usefulness of amalgam, etc., Dental Cosmos, vol. LXIX, 1929, p. 785.
4. Grey, Arthur W.: Contractions and expansions of amalgam with time, Jour. Nat. Dent. Assoc., vol. 9, 1922, p. 324.

4. Grey, Arthur W.: Metallographic phenomena observed in amalgam, Jour. Nat. Dent. Assoc., vol. VI, 1919, p. 513.
5. Crandall, W. G.: Standardizing the amalgam filling, Dental Summary, Vol. 38, 1918, pp. 848, 853.
6. Harper, Wm E.: Is a non-leaking filling necessary to tooth salvation, etc., Jour. Amer. Dent. Assoc., vol. VI, 1919, p. 1099.
7. Harper, Wm. E.: Amalgam, Jour. Amer. Dent. Assoc., vol. XIII, 1926.
8. Grey, Arthur W.: Metallographic phenomena observed in amalgam, Jour. Nat. Dent. Assoc., vol. VI, 1919, p. 513.
9. Ward, Marcus L.: "American Text-book of Operative Dentistry," 6th ed., p. 477.
10. Harper, Wm. E.: Amalgam failures, Jour. Dental Research, June 1927, p. 153.
11. Harper, Wm. E.: Amalgam a typical eutectic mixture, Trans. Dental Soc., N. Y., May 1928, p. 94.
12. Souder, Wilmer: Technological Paper no. 157, Bureau of Standards.
12. Souder, Wilmer: Measurement and application of certain physical properties of dental amalgam, Jour. Dental Research, vol. VII, no. 2, June 1927, p. 153.
12. Souder, Wilmer: Physical properties of dental materials, Jour. Amer. Dent. Assoc., vol. XVI, no. 10, Oct. 1929, p. 1829.
12 Souder, Wilmer: Physical properties of dental materials, Jour. Amer. Dent. Assoc., vol. 12, no. 5, May 1925, p. 509.
13. Coleman, R. L.: Physical properties of dental materials, Jour. Amer. Dent. Assoc., vol. 12, 1925, p. 520.
14. Swanger, Wm. H.: Scientific Paper, Bureau of Standards, no. 552.
15. Peters, C. G.: Technologic Paper no. 157, Bureau of Standards.
16. Taylor, N. O.: Specification for dental amalgam alloys, Jour. Amer. Dent. Assoc., vol. XVII, Jan. 1930, p. 112.
16. Taylor, N. O.: Mechanical amalgamation, Jour. Amer. Dent. Assoc., vol. XVI, no. 4, April 1929, p 583.
16. Taylor, N. O.: Survey of amalgam alloys, Jour. Amer. Dent. Assoc., vol. XVI, no. 4, April 1929, p. 590.

Black, G. V.: "Operative Dentistry," 6th ed., vol. 2.

Black, G. V.: Physical properties of silver-tin amalgams, Dental Cosmos, vol. 38, 1896, p. 982.

Hanks, Jno. T.: Amalgam restorations, Dental Cosmos, Aug. 1928, p. 824.

Harper, Wm E.: Modern amalgam alloys, Jour. Amer. Dent. Assoc., Aug. 1926.

Harper, Wm. E.: Amalgam failures, Jour. Dental Research, vol. VII, no. 2, June 1927, p 153.

Wiun, P. G.: Copper amalgam, Dental Cosmos, vol. 69, no. 12, Dec. 1927, p. 1306.

Burgess, Geo. K.: Dental research at Bureau of Standards, Jour. Amer. Dent. Assoc., vol. XV, no. 6, June 1928.

Ward, Marcus L.: Metallurgical data, Jour. Amer. Dent. Assoc., April 1929.

Rosenhain, Walter: Dental alloys, British Dental Jour., vol. XLVIII, no. 12, 13, 14, 15, 1927.

Souder, Wilmer: Measurement of certain physical properties of amalgam, Jour. Dental Research, vol. VII, no. 2, June 1927, p. 173.

Byrnes, Ralph R.: Control of caries in posterior teeth by fillings, Jour. Amer. Dent. Assoc., May 1929, p. 843.

Paffenbarger, Geo. C. and Sweeney, W. T.: Jour. Amer. Dent. Assoc., April 1934, p. 658.

CHAPTER XVIII

THE NON-PLASTIC RESTORATIVE MATERIALS—GOLD—PHYSICAL AND METALLURGICAL PROPERTIES—METHOD OF MANIPULATION

The Plastic Filling Materials, which include guttapercha, cements, and amalgams, have been discussed in previous chapters. These substances are placed in the cavity prepared for their reception while in a soft or plastic state, and later, through a process of crystallization (oxyphosphates and amalgams), or of gelation (silicates), become a hard mass, capable of resisting attrition. The non-plastics (gold and tin) are either wedged into place between the opposing walls of the cavity (in the absence of cohesion), or are adapted, piece by piece, through a process of welding in the cold state, each particle adhering to the other (cohesion), as the building of the filling progresses.

GOLD

Owing to the fact that the plastics are subject to change of form during the hardening process, and are lacking in crushing resistance and edge strength, as compared with most of the non-plastics, they are not nearly so permanent in character. From a standpoint of lasting qualities, gold is the king of filling materials, and where it can be properly adapted the cohesive form is the material indicated, especially in cases where great masticatory stress will be applied and where fermentation and putrefaction are notably rampant. Non-cohesive gold is not used to any great extent today, except in special cases. The working of this material seems to be becoming, more and more, a lost art. This is in many respects to be regretted, since it has many excellent qualities, which especially recommend it under certain circumstances. Its use in combination with cohesive gold has many advantages. The use of tin as a filling material has been quite largely abandoned.

Since the introduction of the modern cast gold inlay and the silicates, the use of cohesive gold has diminished. This is to be deplored, since there is no material which can compare with it as a preserver of tooth structure. However, gold as a filling material still occupies an important place in dentistry, and will probably continue to do so for a long time.

The principal disadvantages of the cohesive gold filling are the time required for its introduction into lárge cavities, and the physical and nervous strain resulting from its manipulation, on both patient and operator.

The many failures resulting from an indiscriminate use of the gold inlay and the silicates by the profession during the past decade have gradually lead to a revival of interest in the cohesive gold filling and it is slowly returning to the place which it deserves. The following significant words of Dr. C. N. Johnson in the Journal of the American Dental Association, November 1928, Vol. XV, No. 11, page 2051 are particularly *apropos* in this connection. "If the romance of dentistry is ever written, gold foil will be one of the leading characters. If the full story of dentistry's service to humanity is ever told, gold foil must be given the major credit for this service. If the palm is ever yielded to dentistry for the development of an unusual technical superiority over other professional callings, gold foil must be accorded the chief honor. If the source is sought for the outstanding achievement in saving the natural teeth after they are attacked by decay, gold foil must claim its full share in this beneficent function.

"Thus when any adequate consideration is given dentistry, gold foil must be acknowledged as a prominent factor in its development. Never has any one material so signally stamped its individuality and superiority on any calling as has gold foil on dentistry.

"I have on many occasions made the statement, which I now repeat, that there never has, in the alchemy of nature, been a material produced that will so surely save a tooth as a well adapted, well inserted, well condensed, well contoured and well finished gold foil filling. This fact holds as true today as it ever did. Foil has not lost its virtue, nor has the manufacturer failed us.

"The value of gold foil in modern practice is found in its application to such cases as pit and fissure cavities, to all cavities in the molars and bicuspids where access is not too difficult and where the tension is not too great on the patient—in other words, where a good technic may be obtained without undue stress—and to all cavities in the anterior teeth where esthetics may be sacrificed for utility and length of service.

"With a full recognition of the exceptions to these cases, there still remains a wide field for the legitimate use of foil, and to ignore its use under proper indications is to fall far short of the best service to the patient. As has already been said, there is no material as reliable as this and to discard it because of its exactions or its few limitations, in the face of its manifest and manifold virtues, is either to ignore unlimited opportunity for the best service, or to shirk supinely an insistent and moral responsibility."

This trend back to gold as a restorer of natural tooth structure is in evidence on every side. It is an expression of the conviction on the part of the leading minds in the operative field that restoration of function should be given first consideration.

CHARACTERISTICS OF GOLD AS A FILLING MATERIAL

Gold is one of the first metals used by man, and, owing to its varied and remarkable properties and uses, as well as its intrinsic value, it is recognized as the most noble of metals. From the earliest historic records, down through the ages, it has played a prominent part in the development of our present knowledge of metallurgy. The recent introduction of several colloidal forms for therapeutic use in malignant disease is but a revival and development of the crude art of the ancient alchemists who spoke of it in this form as *aurum potabile* (drinkable gold). Gold foil for filling purposes was introduced in America by Robert Woffendale in 1795. The discovery of its adhesive properties is attributed to Robert Arthur in 1855.

Gold possesses a number of important characteristics, which render it of special value as a filling material. These characteristics may be summarized as follows, viz:

First.—Cohesiveness, to a greater extent than any other metal. This quality depends largely on purity. The best golds for filling purposes are about 999 parts in 1,000 pure gold.

Second.—Softness during manipulation. This quality depends largely on purity.

Third.—Malleability; exceeding all other metals in this respect. It may be reduced by beating to 1/250,000 of an inch in thickness. Reaumur is stated to have produced a sheet 0.00000087 of an inch thick.

Fourth.—Ductility. It is the most ductile of all metals. One grain of pure gold may be drawn into a wire nearly five hundred feet long.

Fifth.—Hardness in bulk form. Gold is about one-third as hard as the diamond. This property is largely increased by alloying and by hammering or rolling. Its Brinell hardness is given as 48.0 in comparison with copper 74.0 and silver 59.0. Tested on a Shore Scleroscope the following values were determined by Ward[1] for 24 karat gold; viz.: cast gold 4.9, rolled gold 33.0, annealed after rolling 5.8.

Sixth.—Tensile strength, being capable of holding a weight of seven tons per square inch, according to Hiorns.

Seventh.—Weldability in the cold state. Most other metals must be heated.

Eighth.—Minimum tendency to flow, in contradistinction to tin.

Ninth.—Co-efficient of expansion, 14.4, which is near 11.4, the co-efficient of expansion of the crown of a tooth.

Tenth.—Thermal and electric conductivity 53.20 and 77.96, respectively, as compared with the thermal conductivity of copper (73.60) and silver (100); and the electric conductivity of copper (99.95) and silver (100).

MANUFACTURE OF GOLD FOIL

The process of manufacture of gold for filling purposes is interesting. The foils are made from pure metal by the processes of beating and rolling. Absolute purity is essential in the manufacture of foils.

All light-weight foils are produced by beating, and heavy foils by rolling.

The bullion (pure metal) is first melted and poured into ingots of suitable size; these are then rolled by machinery into thin ribbons about one inch wide and a little thicker than ordinary paper. The thickness is regulated by the weight of the foil to be produced. The ribbons are now cut into one inch squares, each weighing three, four, six, ten grains, etc., depending on the weight of the foil desired.

These squares (one-inch) are then laid between sheets of gold-beater's skins, made from intestines of bullocks, or of vellum paper. These skins or vellum paper are cut into five-inch squares, and many of these are piled one upon the other, with squares of rolled gold interposed. The pile is now wrapped in heavy parchment, and so bound that all of the edges are well protected.

The wrapped package is then placed upon a heavy polished stone block, approximately three feet high by fifteen inches square, the block resting upon a wooden foundation which is set in the ground three or four feet to give it solidity. With a large, round-faced mallet, the package is then beaten with heavy blows, being turned slightly after each stroke of the mallet. The time consumed in the beating process usually is from two to three hours.

After beating of the foil to the desired thinness, the leaves are removed, trimmed and placed in paper books, ready for dispensing. Rolled gold is made by passing it through specially-prepared rolling mills until the thickness required is obtained. All foils, after beating or rolling, are non-cohesive. The cohesive property is developed by a process of slow heating or annealing.

FIBROUS AND CRYSTALLINE GOLDS

Gold, for filling purposes, is *classified* as far as its minute or microscopic structure is concerned, into two varieties, viz.:

First.—Fibrous Gold: made after the method just described.

Second.—Crystalline Gold: made by chemical precipitation or electro-deposition.

If these are examined under the microscope, the fibrous forms are seen to consist of numerous fibers interlacing each other in every direction; while the crystalline forms appear more granular in character. For this reason the fibrous forms make the stronger fillings, although they have a tendency to draw away from cavity walls while being manipulated, owing to a certain amount of resilience or spring in the fibers. The crystalline forms do not possess this tendency, and are more easily manipulated, but are deceptive and treacherous preparations for students' use, on account of their easy working properties. Sponge gold, a crystalline form, was introduced into dentistry in 1853. Dr. W. H. Dwinnelle of New York called attention to the advantages of the contour gold filling in 1854, while Dr. Robert Arthur suggested the use of cohesive foil in 1855. Fibrous golds are supplied in the form of sheets about four inches square, ranging in numbers 2, 3, 4, 5, 6, 8, 10. The higher numbers are rolled by the manufacturers from an ingot, while the lower numbers are beaten by machinery. These numbers indicate the number of grains to the sheet, number four foil containing four grains, number ten foil, ten grains, etc. They are also dispensed in the form of rolls and cylinders or pellets of various sizes or weights.

Fibrous golds are classified into (*a*) Cohesive; (*b*) Semi-cohesive; (*c*) Non-cohesive.

The cohesive foils are, after being rolled or beaten, annealed by heat and put up in books containing one-eighth ounce, or in packages containing rolls or cylinders. Before using, the dentist usually re-anneals them, as they will in time lose much of their cohesive property on exposure to the atmosphere, accumulating gases, which may be driven off by heat.

The non-cohesive foils have deposited on their surface certain non-volatile substances, such as salts of iron, sulfur, or phosphorus, which permanently destroy their cohesive property.

Some foils are supplied as semi-cohesive, in which the cohesive property is not developed to its fullest extent. By controlling the annealing, any degree of cohesiveness may be obtained. These latter foils are preferred by some operators. The non-cohesive and semi-cohesive forms are also supplied in rolls, cylinders or in one-eighth ounce books containing sheets or foil, the number running the same as the cohesive foils.

Some prominent forms of crystalline gold are Watt's Crystal Gold, Solila, Corona, Crystal Mat, Keeton, and Moss Fiber. The latter is claimed to be both fibrous and crystalline in nature. These preparations are in the form of strips, bricks, mats, and similar shapes.

Prominent fibrous golds are S. S. White's, Ney's, Williams', McLaughlin's, and Rowan's.

The advantages and disadvantages of Cohesive Gold as a filling material are as follows.

Advantages:

First.—Insolubility in the oral fluids.
Second.—Perfect adaptability to cavity walls, if properly worked.
Third.—Great density, crushing resistance and edge strength.
Fourth.—Low tendency to molecular change.
Fifth.—Capability of receiving and maintaining a high polish.

Disadvantages:

First.—Inharmonious color.
Second.—High conductivity.
Third.—Difficulty of manipulation.

Gold is insoluble in and non-oxidizable by the oral fluids or their contents, consequently, fillings made with it do not discolor or disintegrate. Gold is capable of adaptation to cavity walls with great force and is then capable, if properly condensed and wedged into place, of immediately and permanently sustaining that force, owing to its elasticity and the elasticity of dentin. Dr. G. V. Black in his experiments found the elasticity of dentin to be 5% on cubes 1/10 inch square under a stress of 300 pounds and 7 to 8% under 350 pound stresses. Cubes of unannealed hammered gold were compressed on an average of 2.09% under the same stress, which, if annealed, were compressed on an average of 13.14%. The elasticity or resistance to compression of gold fillings will depend on the amount of hammering used during the introduction into the cavity. The elasticity of dentin and of gold, if taken advantage of in condensing gold fillings willdu proce the most perfect type of adaptation. The grip of the elastic dentin will depend upon the force with which the elastic gold is wedged between opposing cavity walls. This natural elasticity of gold and dentin, together with the indestructibility of the former makes gold preeminent as a filling material.

The crushing resistance of hammered gold is largely due to its density or high specific gravity, its hardness, and its slight elasticity or lack of brittleness, which render it both hard and tough. The hardness of pure gold has previously been given, as tested by the Brinell testing machine and the scleroscope. Most metals are usually soft when cast and hard when hammered. Gold, hardened by hammering, may be softened by annealing.

The strength of gold, when built out to thin edges over long bevels, greatly exceeds that of other filling materials and is due to the qualities just mentioned, as well as to its tenacity and low tendency to flow or change form. Hoffman in his General Metallurgy gives the specific gravity of cast gold as 19.25 and hammered gold as 19.35, while Black in his experiments reported it as 19.22–19.25 for cast and 19.30 for hammered gold.

Cohesive gold is capable of receiving and retaining its polish to a much higher degree than the other filling materials. The thermal and electric conductivity of gold only slightly exceeds that of amalgam. This may readily be provided against, where necessary, by the use of a cavity varnish and cement intermediate.

The chief disadvantage of cohesive gold is the difficulty of learning to properly manipulate it and the strain on patient and operator incident to its introduction. The technic of its manipulation is acquired only after long and intensive study and training. This should be begun in the dental school, stressed by repetition and the performance by the student of as many foil operations as time and conditions will admit, and continued in the early years of practice, until the knowledge of its properties and the utilization of these properties through systematic operative procedure enables him to master its difficulties. There is nothing in the entire college course which will better lead to a development of technical facility and high operative ability than the manipulation of gold foil. Its use develops and demands qualities of cleanliness, exactness, precision, concentration, patience, and perseverance, and produces, as no other material or procedure in dentistry will do, a zeal, a joy and a spiritual uplift from the accomplishment of a fine piece of work well done. The perfection of a technic will reduce the strain of the operation on both the patient and the operator and its proper use, in cases where it is indicated, will also greatly minimize its shortcomings, if they can be called such, in that direction.

The remaining disadvantage, so often stressed, is its conspicuous color. Many Class III cavities may be so prepared that the labial wall is preserved, which will prevent undue display. Also, in the mouths of blonds, the material is seldom objectionable, even in comparatively large cavities, if properly contoured to artistically restore the form and mesio-distal width of the tooth in which it is placed. In some cases the sacrifice of beauty for utility will be desirable, since there is no material at present used which can compare with the permanency of gold foil in cavities in the anterior teeth. Gold may be placed in any portion of the mouth where proper access may be obtained, where its color is not objectionable, and the strength of cavity walls permits.

Non-cohesive gold may be used, on account of its rapidity of manipulation, in simple cavities with four strong walls, located on surfaces not subject to wear. It may also be used in combination with cohesive gold, for beginning fillings on the gingival wall in proximo-occlusal cavities, or on the pulpal wall in occlusal cavities, as a time saver. It is not indicated on surfaces subjected to stress of mastication, or for contour work.

Cohesive gold, though, is now used almost exclusively, on account of its great crushing resistance, its ability to contour and to be built out over long bevels to thin edges, and also on account of greater familiarity on the part of modern operators with its working properties.

FACTORS INFLUENCING SELECTION

The factors which influence or modify the selection of gold as a filling material are as follows:

First.—Physical condition of the patient.

Second.—Mentality and will-power of the patient.

Third.—Age.

Fourth.—Strength of the pericementum and state of development of the root.

Fifth.—Extent and rapidity of caries and hygienic condition of the mouth.

Sixth.—Sensitivity of the dentin.

Seventh.—Strength of cavity walls.

Eighth.—Character of the occlusion, (strength of the bite and character of excursions of the mandible).

Ninth.—Presence or absence of abrasion.

Tenth.—Accessibility of the cavity.

Eleventh.—Skill of the operator.

Twelfth.—Esthetic considerations.

In many instances gold foil would be contra-indicated in the very young, the aged, in convalescent patients, or in those whose physical condition would not permit of their being subjected to prolonged operations. Some patients are unable or unwilling to subject themselves to prolonged or nerve taxing operations of any kind, particularly those who are mentally weak or lacking in will power. Others, even if they are not deficient in this respect, prefer operations of a more temporary nature, rather than afford the time and stamina necessary to obtain the results of which gold is capable. Cohesive gold should not be attempted in cases of undeveloped roots, on account of the force required in its introduction, which would be likely to produce pericemental disturbance. Also, in very young permanent teeth, the peridental membrane is quite thick, and would likely act as an elastic cushion and prevent perfect condensation of the gold.

The care which the patient gives the mouth and the susceptibility to decay will always have a bearing. Gold is the most permanent of the restorative materials and its need will be proportional to the demands for lasting qualities in these cases. Consequently, the more prevalent and rapid the decay and the more uncleanly the mouth, the greater is the indication for the lasting qualities of cohesive gold under these circumstances. In hypersensitive cavities with nervous patients, the use of a plastic material of less permanent nature will sometimes of necessity be required. However, in some of these cases, the use of a cavity varnish and intermediate over the axial or pulpal wall will largely alleviate the difficulty. Cohesive gold would usually be contra-indicated in extensive cavities with weakened walls, certainly unless the latter can be strengthened with cement. However, the time and effort required would usually prohibit its use here anyway, and the gold inlay or a plastic would often be substituted.

The strength of the bite, forward and lateral excursions of the mandible and general type of occlusion should always be studied. Cases with very heavy mastication and wandering type of occlusion subject occlusal surfaces to great stress and wear, often with marked resultant abrasion. Perfectly condensed cohesive gold fillings resist these stresses very well, and are often indicated, except in those involving extensive restorations, when the gold inlay may be preferred. Gold may be used wherever direct access to the cavity may be obtained, where the line of approach is easy, and the angle of force may be correctly applied to accomplish perfect adaptation to cavity walls, provided the other factors mentioned are favorable. Esthetic conditions will always have to be reckoned with in its use in the anterior teeth, but in some cases utility will have to be considered of more importance than harmonious and artistic effect. The ability of the operator will always have to be considered, and in difficult cases his individual skill in the manipulation of the material will often necessarily determine whether gold is to be the material of choice.

Gold is often indicated in children's teeth. It is the ideal material for permanent teeth in the young, if the physical and mental condition of the child, extent of development of the roots, possibility of securing exclusion of moisture, accessibility, and strength of cavity walls permit. No fixed rule as to age can be given; in some children gold may be used at ten years of age; in others not until much later. It is not a question of strength of the tooth tissue, since all of it is abundantly resistant, even at ten or twelve years of age, for condensation of gold; it is rather a question of physical condition and local surroundings.

INDICATIONS FOR THE USE OF GOLD

Gold is the material of preference in all Class I cavities, where sufficient access is obtainable, and the only cavities of this class really difficult of access are buccal and occlusal cavities on third molars. If the skill of the operator does not permit of perfect adaptation to cavity walls in cavities in these teeth, gold should not be attempted. It is the ideal material in Class V cavities of easy access and where it will not be exposed to view. Usually it is contra-indicated in gingival third cavities in anterior teeth freely exposed to view, for esthetic reasons. It is the material of choice in the majority of Class III cavities of small and medium size. In large Class III cavities, it will often be better to use it and sacrifice esthetics for utility and permanence of service. In mesio-occlusal cavities in bicuspids and first molars, it is far superior to the gold inlay or other materials, if the operator possesses the necessary skill for its adaptation. It is usually not indicated in disto-occlusal cavities in molars, where it is difficult to apply correct angles of force in adapting it to cavity walls. It is thus obvious that the material has a very wide range of usefulness in modern practice when it is desired to render the highest type of service.

EFFECT OF VARIOUS SUBSTANCES ON FILLING GOLDS

Ammonia, chlorin gas, hydrogen, hydrogen phosphid, hydrogen sulfid, hydrogen carbid, sulfurous acid gas, iron, sulfur, phosphorus and phosphoric acid gas, deposited on the surface of gold, render it non-cohesive. Some of these substances are used by the manufacturer in the making of non-cohesive and semi-cohesive foils. Some foils are non-cohesive in character, but may be readily transformed into cohesive by annealing. Those of this character have incorporated on their surface volatile substances, readily driven off by heat. Other foils are permanently non-cohesive. These have deposited on their surface a non-volatile substance, such as iron, or some of the sulfur or phosphor combinations. All foils, immediately after beating or rolling, are non-cohesive. Annealing brings out their cohesive properties. Cohesive gold rapidly becomes contaminated from the presence of carbonic acid gas, phosphoric acid gas, sulfuretted hydrogen gas, etc., in the atmosphere, hence the necessity for annealing before use.

A convenient method of keeping foil in the cabinet is to use one variety of foil, that is, cohesive. Expose it constantly to the fumes of ammonia gas, by keeping an open bottle of ammonia in the drawer in which it is kept, which renders it non-cohesive and protects it from contamination by other gases. If the use of the non-cohesive method is desired, use the foil without annealing. If the cohesive method is to be used, anneal it.

DENSITY OF CAST AND HAMMERED GOLD

Dr. G. V. Black conducted numerous experiments to determine differences in density and specific gravity between hammered cohesive gold and cast pure gold inlays. The following table, taken from Black's Operative Dentistry, Vol. II page 233, shows the results obtained from a number of ingots one-tenth of an inch square.

Gold	Specific gravity	Average percent of shortening under stress of 300 lbs.
Cast	19.22 to 19.25	10.14
Hammered	19.3	2.09
Annealed	19.3	13.14

Dr. Black's experiments were made in steel matrices with lateral supporting wall, in the laboratory, and under those conditions showed conclusively that hammered and malleted gold undoubtedly are denser than cast gold. The conditions of working in the mouth, however, are different, and it would be impractical to obtain such density in cavities with wor ithout four walls, in the mouths of patients.

Dr. Black's experiments out of the mouth show greater specific gravity for the malleted and hammered filling. In the mouth it is not possible or practicable to subject fillings to the excessive stress obtained in his laboratory experiments. In addition, a large percentage of gold fillings in the mouth are contour fillings, when the absence of lateral supporting walls undoubtedly results in less density in that class of fillings. That being the case, taking them as a class, the percentage of density is undoubtedly in favor of the cast inlay. Dr. Black claims a difference of slightly more than 2% in density, in favor of the cast inlay, in a large number of old fillings examined in extracted teeth. With many of the modern gold alloys this difference is undoubtedly still greater.

However, stress must be laid on the fact that density and resistance to crushing strength is not always the best test of the utility of gold fillings. Reasonable strength must be attained, but perfection of adaptation to cavity walls is even of greater importance, to prevent leakage. Much hammering will produce a dense, hard, and tough filling, but unless the proper methods are used, close adaption to the walls is not produced and a defective filling results. According to Black a gold filling of less specific gravity than 15 will allow penetration of moisture into its substance, so that this must be considered the minimum density allowable to prevent entrance of fluids into the body of the filling. In fillings on labial or buccal surfaces not exposed to stress, a density slightly above this figure would probably be sufficient, provided perfect adaptation is obtained, but on other surfaces a density of 18 should be attained to resist crushing stresses. This matter is further discussed in the chapters on Gold Inlays.

PREPARATION OF GOLD FOR FILLING

Cohesive and non-cohesive gold is supplied by the manufacturer in the form of (1) sheets of foil, rolls, and cylinders, and in (2) mats, strips, pellets, or cushions, the latter being usually of the crystalline varieties. If desired, the operator or his assistant may prepare various forms after the following methods:

Method of Preparing the Roll and Ribbon. *The Roll.*—(*a*) Cut a sheet of foil into quarters and place a section near one end of a smooth towel, which has been folded lengthwise; (*b*) place the other end of the towel over the foil, and then, bringing it in contact with it, quickly push the towel from you in such a manner as to roll the foil into a loose roll; (*c*) repeat the process until the roll is as small as desired. See

Figs. 512 and 513. (Rolls also may be obtained ready prepared by the manufacturer.)

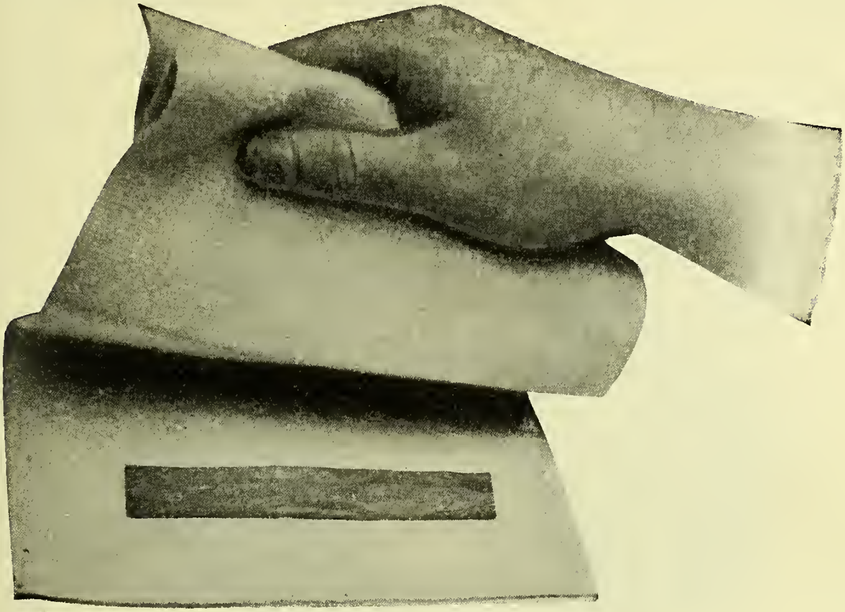


FIG. 512.—Preparing the roll.

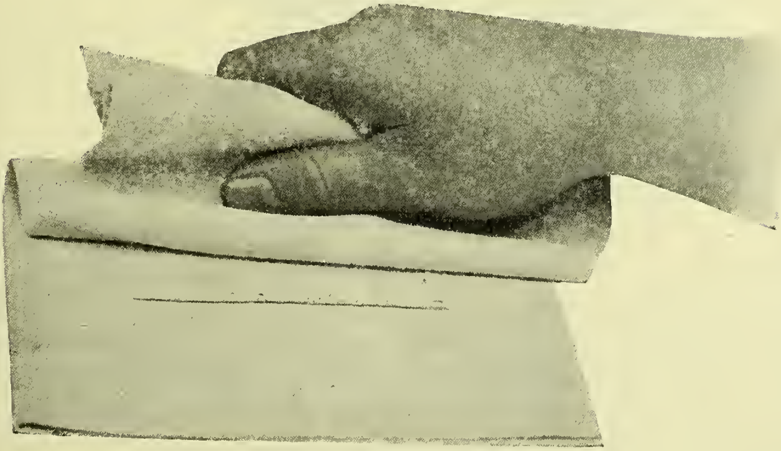


FIG. 513.—The roll completed.

The Ribbon.—(*a*) Cut the foil into quarters, as before, and lay a section on a folded towel, or napkin, or a piece of chamois or spunk, held in the left hand; (*b*) with a large, clean plaster spatula, or preferably a gold folder, fold the foil lengthwise, by placing the folder in the center of the section and bringing together the folds of the towel or other article used, by closing the hand; (*c*) repeat the operation, continuing to fold smaller and smaller until the ribbon is the desired width. Fig. 514.

Method of Preparing the Cylinder.—Roll a ribbon (made from a quarter, third or half of a sheet of foil) on a three- four- or five-sided smooth broach. The size of the cylinder thus formed will be regulated by the amount of gold used and the length of ribbon, while the length of the cylinder will be regulated by the width of the ribbon. Various sizes and lengths are required, depending on the size and depth of the cavity. Gold cylinders in both cohesive and non-cohesive forms are also prepared ready for use by the manufacturer. Fig. 515.

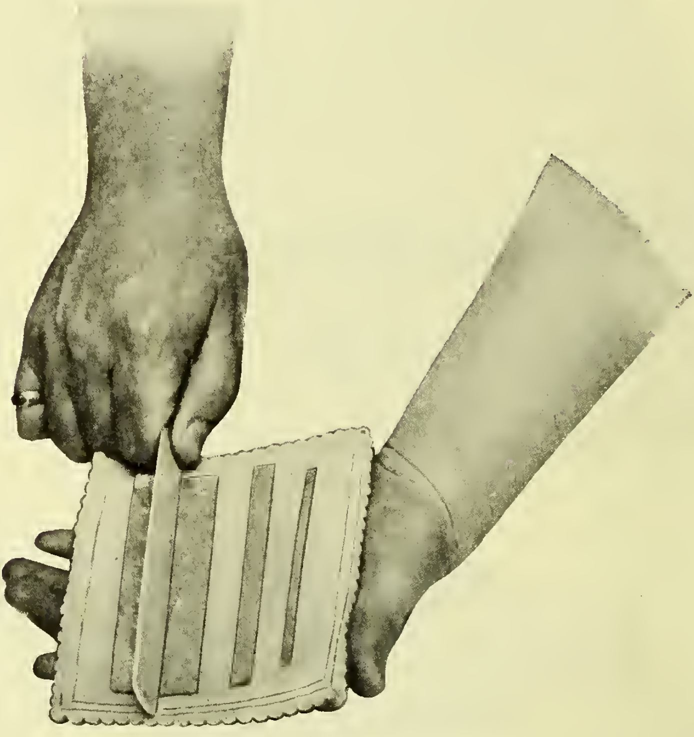


Fig. 514.—Folding the ribbon.

Method of Preparing the Cushion or Mat.—Fold a ribbon lengthwise upon itself with a spatula or gold folder, until made into a mat or cushion. The size required will depend on the size of the cavity, and may be varied by regulating the width of the ribbon, the amount of gold used, and the number of folds. Another method consists in rolling a cylinder on a flat-sided broach, and then, after withdrawal from the broach, flattening it into mat or cushion form. Of these various forms the roll and the cylinder are usually preferred.

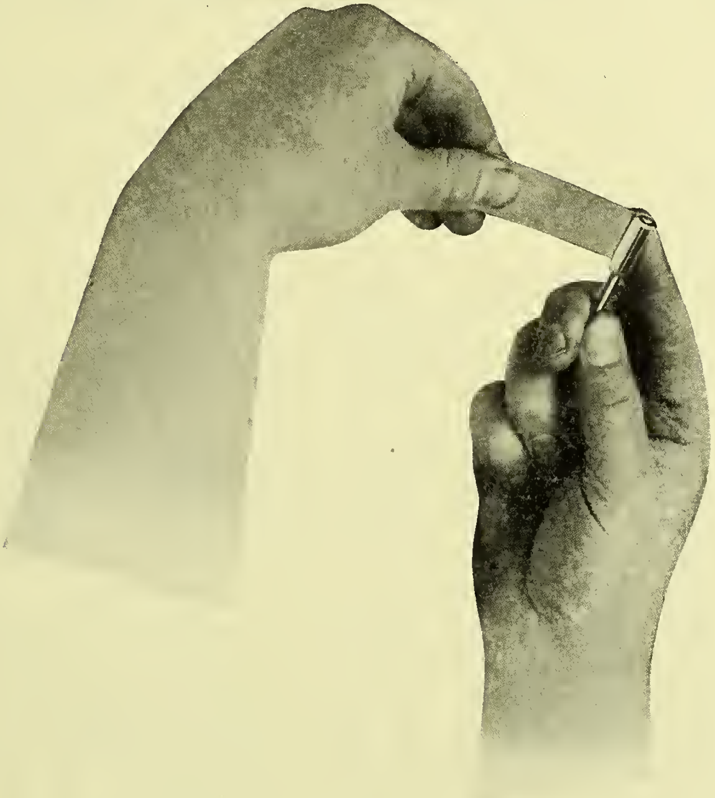


FIG. 515.—Preparing the cylinder. The cylinder and broach are shown much enlarged.

METHODS OF ANNEALING GOLD BY THE DENTIST

Although cohesive gold is annealed by the manufacturer before dispensing, it quickly becomes contaminated by the presence of carbonic acid, sulfuretted hydrogen and other gases in the atmosphere of poorly ventilated or unhygienic rooms or surroundings. Carbonic acid gas is derived from the exhalations of the lungs and other sources, while sulfuretted hydrogen gas, as well as phosphoric acid gas result from decaying animal or vegetable matter, such as blood, pus and other substances left on soiled linen, in the fountain cuspidors or receptacles in the dental office. Sulfurous acid and phosphoric acid gases also are derived from burning matches, while the former emanates from sulfurous coal gases in the air and from rubber and vulcanite. Immense amounts of this gas may be liberated from a vulcanizer, or during the trimming of vulcanite dentures and it is constantly being liberated from rubber gloves and similar articles.

Two general methods of annealing are in use, one of which has many advantages, while the other is poor.

First Method.—Cut the gold into small pieces and lay on the tray of a gold annealer, thus preventing contact with the impure gases of the flame, as well as the tendency to overheating and irregular annealing. The best form of annealer is the electric, though good results are obtained with the ordinary forms, constructed for use on the alcohol lamp or Bunsen burner.

Second Method.—Grasp the gold near one end with foil carriers and pass back and forth over the flame of an alcohol lamp or Bunsen burner. Then grasp at another point, and repeat the procedure, heating the gold to a dull red color, being careful not to overheat or melt any portion.

There are three disadvantages in this method: (1) the danger of overheating or melting the gold, rendering it brittle and destroying its softness; (2) the danger of overheating one part and underheating another; (3) the danger of gases from an impure gas flame, or a charred wick of an alcohol flame, destroying some of the natural cohesive property of the gold. The point first grasped by the pliers is not annealed, because the handles of the pliers carry off the heat at that point; hence the necessity of grasping at a new point after the first annealing, and repeating the process, to prevent the occurrence of partially annealed spots in the gold, with the resultant tendency to pitting the filling. The use of a gold annealer is the most satisfactory method.

If a mica or soapstone tray is used, the dentist should be careful to see that the flame of the lamp is given sufficient heat to properly anneal the gold, else poor fillings from failure to bring out its full cohesive property will be the result. Too much heat is likely to burn the gold and make it brittle and hard working. Great care should be observed to obtain just the right degree of heat.

For annealing in the open flame a temperature of about eleven hundred degrees Fahrenheit is required. In bright daylight the red color will not appear, but on dark days a dull red color should be apparent, if proper annealing is accomplished. With the use of an annealer, this temperature is unnecessary, undesirable, and will likely overheat the gold. With this appliance lower temperature and longer annealing are indicated and produce better results.

RATIONALE OF PLUGGING GOLD

Pieces of annealed cohesive gold readily adhere to each other when brought in contact. With great power or "load," rapid friction, and small thin layers of gold, it would be possible to build gold fillings by burnishing with smooth burnishers. The smaller the surfaces and the thinner the layers, the less the load and speed required to accomplish the operation. This would, however, be a laborious process on patient and operator, consequently serrated pluggers are used, made of a series of pyramids, which act as so many wedges, exerting great lateral power on their polished sides. The use of the plugger, then, is after all a system of burnishing, designed to lessen the strain of the operation on the operator and patient. Fig. 516.

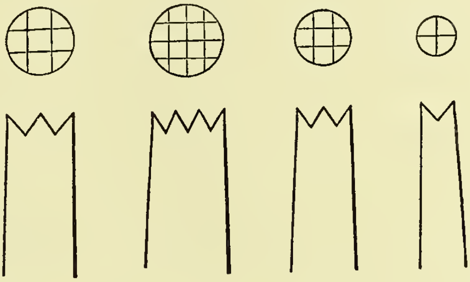


FIG. 516.—Diagram showing serrations in the nibs of some of the round pluggers in the Black set, much enlarged.

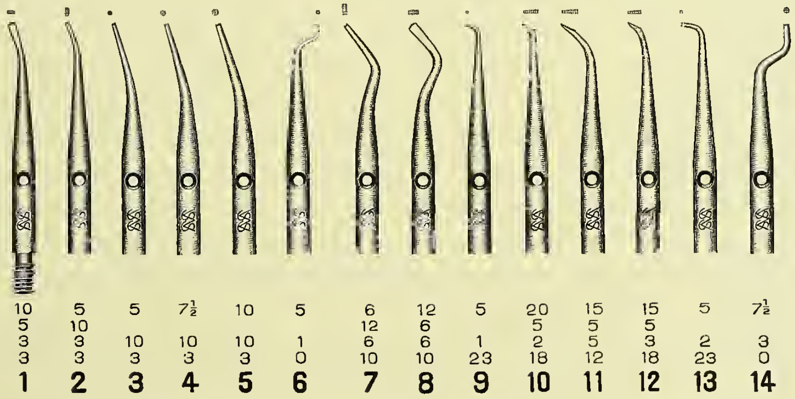


FIG. 517.—Black set of cone socket pluggers. Formula names are shown.

Gold pluggers are made with numerous serrations on the nib, these serrations being of a wedge or pyramidal shape. A set of gold pluggers should possess serrations of the same size in each instrument, in order that when change of instruments is made during the gold-building operation, the pyramids may properly interdigitate. In case instruments with different size serrations are used, when a change to a new instrument is made, the surface of the gold should be gone over with the new instrument before adding a fresh piece of gold. In addition, care should be taken to avoid slipping of the plugger over the gold or turning of the plugger on its axis during its manipulation. Fig. 517.

NATURE OF FORCES REQUIRED IN BUILDING COHESIVE GOLD

In plugging cohesive gold, the application of the force required to weld and condense it is accomplished by means of hand pressure, the hand mallet or some form of mechanical mallet. The use of hand pressure alone is contra-indicated, except for anchoring the gold in point or convenience angles and in placing it in localities where the direction of force required will not allow the use of the other methods. Even under these circumstances a plugger point of very small diameter, 0.5 millimeters, which does not require great power in its manipulation must be used. Dr. Black and many of his followers recommend the hand mallet used by an assistant, the dentist directing the plugger point and holding it in proper contact and relation with the gold being built. The hand mallet for percussion was introduced into dentistry by Dr. E. Meritt of Pittsburgh in 1838. This was before the introduction of cohesive gold. It was later re-introduced by Dr. W. H. Atkinson in 1861. This method is still in use by many excellent operators and is valuable because of the "dead" nature of the blow delivered, which seems to produce less strain on the patient. However, it has been largely superseded since the introduction of various forms of mechanical mallet, which do not require the services of an assistant. Various types of these have been introduced from time to time, including the pneumatic, engine, automatic and electric mallets. The pneumatic mallet, in which the blow was delivered by means of air pressure, and the engine mallet, which was attached to the hand piece of the engine, rapid blows being delivered with its revolution, are largely abandoned. The automatic mallet, in which the blows are delivered by the releasing of a spiral spring is now most frequently used, while the electric mallet, a very rapid, but dangerous appliance in the hands of the inexperienced, is still considered valuable by a few operators. The Snow and Lewis Automatic mallet was patented in 1866. Fig. 518.

To properly condense gold with the least pain to the patient, the mallet force should be combined with a certain amount of hand pressure.

The nib of the plugger should first be placed firmly in contact with the gold in such a manner as to slightly condense it and also to render tense the fibers of the peridental membrane and prevent too much jarring of the tooth. Then two blows of the mallet should instantly follow in rapid succession, when the plugger is moved three-fourths the diameter of its nib and the procedure is repeated, continuing in this manner until a layer of gold is condensed. This procedure is readily accomplished with the hand mallet, but may be copied with practice with the automatic. In cases where a direct line of force cannot be applied, hand pressure or the use of reverse action pluggers with the hand or automatic mallet is necessary.

In plugging cohesive gold it is necessary for the student to become thoroughly familiar with the nature and the effect of the blows to be delivered with the mallet. In this study (1) the weight and velocity of the blow, (2) the character of resistance of the substance hit and being condensed and (3) the area of the surface on which the blow is delivered must be considered. These factors must be correlated to produce correct results. The blow must be carefully adjusted to the work to be performed. It must not be too strong, nor too light, else failure to accomplish the purpose desired will result. The area of the nib of the plugger must be fitted to the force behind the blow, since we depend on the force of the blow at the moment of contact to produce results. This may be measured in pounds or kilograms. Mention previously has been made of the thrust dynamometer for testing the finger power of dentists, which was found to average 15 pounds to the thrust, using the pen grasp. This is about the average power required to properly condense gold with a plugger 1 millimeter in diameter and would rapidly tire the operator, if hand pressure alone were used to build gold fillings, hence the necessity for mallet pressure, with which the necessary force may readily and easily be delivered. If too much force is used, the plugger point will penetrate too deeply, the gold will be chopped up and dangerous strain will be produced, resulting in traumatic pericementitis and tenderness of the tooth. If insufficient force is applied, imperfect condensation and adaptation to cavity walls occurs and a pitty and leaky filling results. In laboratory experi-

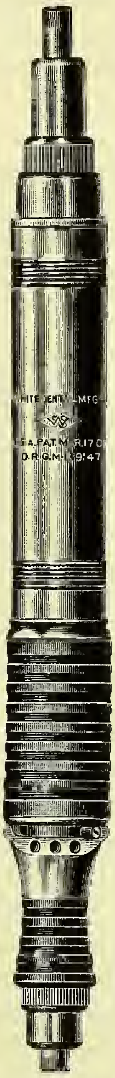


FIG. 518.—Automatic mallet. Direct and back action.

ments, it is found that the force of the blow is dissipated by placing an elastic substance or cushion under the steel matrix in which the gold is being condensed. Under these circumstances the force and velocity of the blow must be increased, depending on the thickness and elasticity of the material supporting the steel matrix, to produce desired results. In operating in the mouth, some teeth have very thin peridental membranes, in which the resistance to the blow is slight, while others, particularly in the young have thick peridental membranes, which give more to the blow and reduce its pounds force. This must be reckoned with in gold building operations, particularly in the mouths of children. The force will also be dissipated to a degree by the movement or "give" of the mandible in operating on lower teeth and by the spring of the steel in the shank of contra-angled and long shank instruments. Under all these circumstances the force of the blow must be increased to produce the desired result. At the same time, the danger of trauma to the delicate pericemental fibers must constantly be kept in mind. In using hand pressure, these differences are nil, but with the mallet, they are very important. The force required, which was the first factor mentioned is proportionate to the size of the nib of the plugger, viz. the smaller the diameter of the plugger, the less force required to produce condensation of the gold. With increase in diameter of the plugger the area of the nib and the pounds force required is rapidly increased. The gold being condensed represents the second factor previously mentioned in this consideration, viz. the character of resistance of the substance hit, while the area of the surface on which the blow is delivered is the third factor. The importance of correlation of these factors cannot be too much emphasized. With a plugger point 0.5 millimeters in diameter, area 0.1963 square millimeters, the force required for condensation of the gold has been found to average 3.75 pounds stress; a plugger point 0.75 millimeters in diameter represents an area of 0.4417 and requires 8.43 pounds stress; while one of 1 millimeter in diameter shows an area of 0.7854 and requires a stress of 15 pounds. Plugger points larger than 1 millimeter in diameter should not be used for general gold building on account of the high stresses required to produce proper welding and density, with resultant strain on patient, operator and pericementum. If foot pluggers of larger diameter than this are used for building gold, only the toe or heel of the instrument should be used, to lessen the area of gold under the nib. Thus it is seen that the range in the size of plugger points must usually be limited between 0.5 and 1 millimeter in diameter. However, the form of the plugger may vary, depending on the purpose for which it is intended. The following table represents the relationship between diameter, area and pounds force required in plugger points of various sizes. Note that when the diameter of the instrument is doubled the area and pounds force are increased four times.

Table Showing Relation between Diameter, Area, and Pounds Stress

Diam. in mm.	Area in sq. mm.	Pounds force required
0.5	0.1963	3.75
0.75	0.4417	8.43
1.00	0.7854	15.00
1.25	1.227	23.43
1.5	1.767	33.25
2.0	3.141	60.00
2.5	4.908	93.75

The force applied in plugging gold will be regulated by the capability of the peridental membrane to resist the pressure, by the density and crushing resistance demanded in the filling, as well as by the other factors mentioned. Teeth normally subjected to vigorous mastication will bear much heavier blows than those which are used very lightly, on account of the resultant strength and vitality of the pericementum and surrounding bone. Fillings placed on surfaces not subjected to heavy mastication will not require the heavy condensation of those built on incisal or occlusal surfaces of the teeth of individuals accustomed to vigorous mastication. Variations of the strength of the bite on various teeth and in different individuals, as measured by the gnathodynamometer have been previously discussed. The force required for the mastication of different types of food as measured by the phagodynamometer has also been given. These conditions must always be taken into consideration. In every case, a density that will prevent entrance of moisture into the body of the filling and a perfect adaptation of the gold to the margins to prevent leakage is necessary. The density necessary to produce adequate crushing resistance must also be attained and will be regulated by the stresses to be applied during mastication.

Angle of Force.—The direction of force should never be perpendicular to the plane of the cavity wall being covered. This would produce a buckling up of the gold and a drawing away from the walls. This may be readily illustrated by laying a piece of gold plate on an anvil, holding an instrument at right angles to it and striking it with the mallet. Owing to the elasticity and spring of the gold, it will curl away from the sides of the instrument and it will be impossible to restore it to its original form by hammering. Consequently, whenever possible the angle of force should be inclined 12 centigrades from the perpendicular to the plane of the wall. In occlusal and gingival third cavities, the shaft of the plugger should be inclined at least 6 centrigrades, better 12 centrigrades if possible, away from the lateral walls. The same holds true in proximo-occlusal cavities, the angle of force being inclined towards the buccal and lingual walls at least 6 centrigrades. This will prevent the tendency of the gold to spring away from the floor or wall of the cavity on which the gold is being condensed and drive the gold ahead of the plugger toward the lateral walls. In starting the gold in point angles and building along line angles, the effort should always be made to bi-sect the angle, to prevent the tendency toward buckling of the gold and to wedge it into place against the walls forming the angle.

Wedging the Gold.—The gold should be strongly wedged into position between opposing walls to take advantage of the elasticity of the dentin and the slightly compensating elasticity of the gold. This is accomplished by using correct angles of force, by systematic stepping of the plugger from the central part of the mat of gold being condensed, toward the lateral walls, and by finally condensing and wedging the gold between that previously stepped and condensed and the walls approached. In stepping the gold, the plugger point should be stepped in definite lines, parallel to the wall approached, moving it about three-fourths the diameter of the nib before delivering the blow. Begin the stepping near the center of the cavity and step a line of blows parallel to the lateral wall. Then step another line in a similar manner and another if necessary, stepping not toward the lateral wall but parallel with it. The final line of steps should wedge the gold between the wall and the gold previously condensed. The lines of force should be applied at an angle of from 6 to 12 centigrades toward the lateral walls. To secure perfect adaptation and to take the highest advantage of the wedging principle, the condensation against the cavity wall should be sufficient to spread the gold against it with considerable force. Additional force may be applied by using an additional number of blows, by increasing the mallet pressure or by changing to a smaller plugger and repeating the line of blows. In no instance should an attempt be made to at once cover the floor of the gingival or pulpal walls of a cavity with a thin layer of gold. This will increase the difficulty of plugging and prevent perfect adaptation. The gold should rather be built up first along a line angle, bisecting it and gradually building out on to the two walls forming the line angle in the shape of a triangular bar, until a considerable body of gold is obtained.

In simple cavities and in the occlusal part of Class II cavities, the gold should then be continued in a similar manner along another line angle, and then another, building up against the lateral walls and over the floor in triangular form and leaving the central portion at a lower level until the cavo-surface angles are covered, when the central portion may be finally levelled up. The same general idea should be followed on the gingival wall of Class II, III, and IV cavities. First, anchor the gold in the point angle and then build a triangular bar along the gingivo-axial line angle over into the opposite point angle, when the bar is anchored securely in place. Bisect the angle formed by the junction of the axial and gingival walls and continue to build gold equally against these walls until the gingival wall is finally covered, when the gold is then levelled up on the gingival wall by changing the angle of force and adding the gold in layers extending from the gingival edge of the triangular bar to the main body of gold. In levelling up here, the angle of force should be 6 to 12 centigrades toward the labial or buccal walls as these are approached, and toward the lingual walls as they are built against.

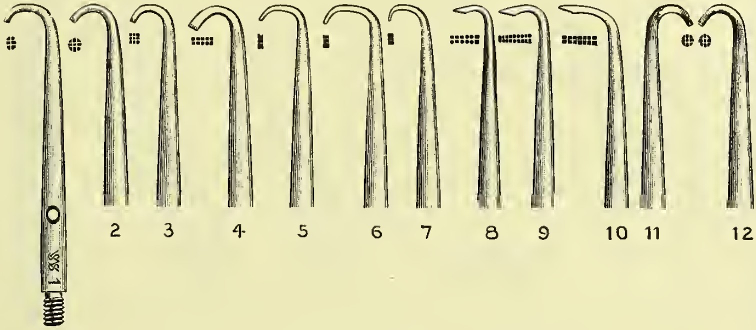


FIG. 519.—Abbot back action pluggers.

Plugger Points.—Gold pluggers should be frequently cleansed with alcohol, ether, or chloroform, kept bright, clean and free from deposits of all kinds. Fig. 521 illustrates the Black set of 14 gold pluggers. They may be obtained interchangeable for automatic mallet or for cone socket handles to be used with hand mallet. Fig. 519 shows a set of Abbott's back-action pluggers, for use in the automatic mallet, to reach areas where direct approach cannot be obtained The Woodbury set, containing pluggers for both cohesive and non-cohesive gold is seen in

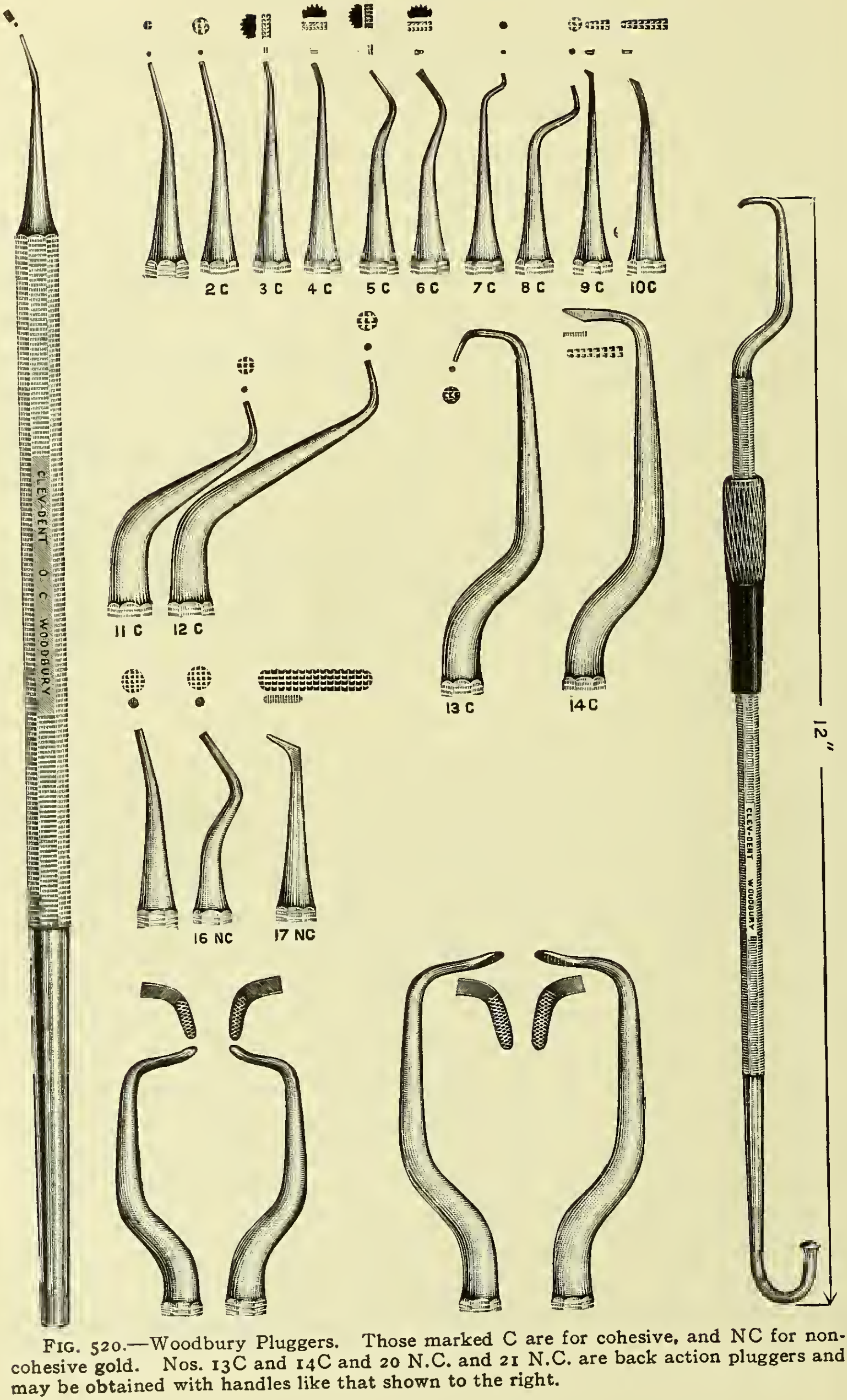


FIG. 520.—Woodbury Pluggers. Those marked C are for cohesive, and NC for non-cohesive gold. Nos. 13C and 14C and 20 N.C. and 21 N.C. are back action pluggers and may be obtained with handles like that shown to the right.

Fig. 520. In this set are shown both direct and back action pluggers, all intended for hand mallet alone. The impacting area of gold pluggers may be either round, square, parallelogram or foot form. Each of these forms has special uses in different localities. The Black and Woodbury sets are given formula names after the same methods as are used in indicating the measurements of cutting instruments.

The size of the working face is given in tenths of a millimeter, the length of the nib in millimeters and the angle in centigrades. If the plugger is round, only one dimension of the face is given, while with parallelograms two dimensions are indicated. In the Black set, the round pluggers are in three sizes, 5-10-3, 7½-10-3, and 10-10-3. There are two pairs of parallelograms, each pair consisting of a hatchet and a hoe shape. In the hatchet shape the larger dimension of the face is given first in the formula, while in the hoe shape the smaller dimension is the first figure. The formula of the smaller pair is 10-5-3-3 and 5-10-3-3, ten representing in the hatchet form the length and five the width of the working face in tenths of a millimeter. In the hoe, the first figure, 5, represents the width of the face and ten, the length of the face in tenths of a millimeter. The third figure, 3, represents the length of the nib from the face to the angle in millimeters and the fourth figure, 3, gives the angle in centigrades. The formula of the larger pair is 12-6-6-10, and 6-12-6-10, the first mentioned being the hatchet and the second being the hoe. The foot pluggers present a toe and a heel and their formula names are given in a similar manner. There are three foot pluggers in the set, viz. 20-5-2-18, 15-5-5-12,

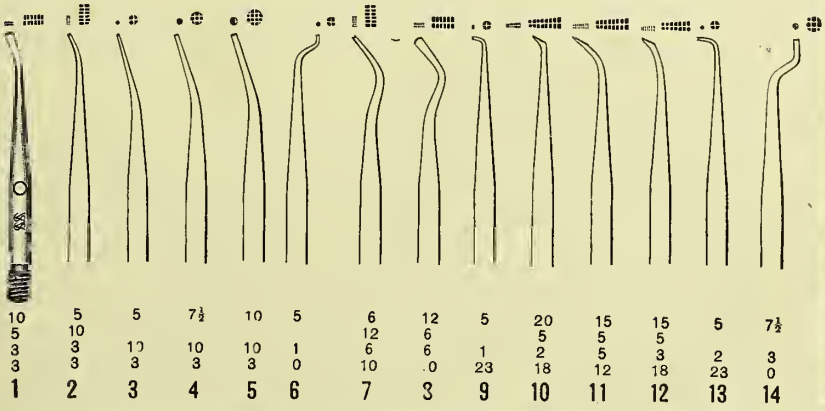


FIG. 521.—Black set of 14 pluggers. May be obtained for use in the automatic mallet, with hand pressure or with the hand mallet.

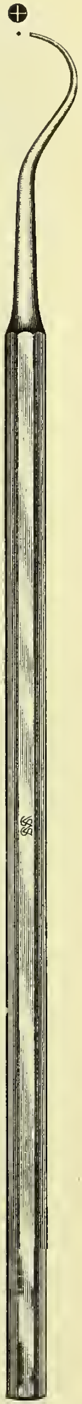


FIG. 522. Black holding instrument or assistant plugger.

and 15-5-3-18. The set includes two bayonet shaped pluggers, 5-1-0 and 7½-3-0; also 23 angle round pluggers, 5-1-23, and 5-2-23. All of these pluggers should at once be studied, their formula names and uses learned.

The smallest round plugger, 5-10-3, is used in conjunction with a holding instrument for starting gold in convenience angles. A holding instrument is shown in Fig. 522. Round plugger 7½-10-3 may be used for the same purpose in larger convenience angles and also for some parts of general gold building. As a rule it should not be used for wedging against walls of cavities. The large 10-10-3 may be used in any location where a large body of gold is being built, except for wedging against walls.

The small parallelograms, 10-5-3-3 and 5-10-3-3 are used for general gold building in anterior teeth and in wedging against walls in bicuspids and molars. The large pair, 12-6-6-10, and 6-12-6-10 is used for condensing and general gold building in bicuspids and molars. The foot pluggers, three sizes and shapes, are used for reaching into embrasures and condensing gold over labial, buccal, lingual, and gingival margins. The bayonets, 5-1-0 and 7½-3-0, may be used in inaccessible localities and for condensing gold along the labial walls of Class III cavities in incisors. Number 5-1-0 is also sometimes used for filling convenience angles. The 23 centigrade pluggers are used with hand pressure for filling incisal retentions in Class III cavities and for work in other inaccessable localities. Other pluggers in the Black set, not shown, are reverse action pluggers to be used with the hand mallet for distal cavities in lower bicuspids and molars, and direct action quadrangle forms for after condensation on gingival margins. The Abbott back action pluggers are for use in distal cavities, where direct angles of force may not be applied with the other forms mentioned.

In the Woodbury set, Fig. 520, are seen rounds, parallelograms, bayonets, foot pluggers, reverse action pluggers, and larger forms (marked N.C.) for non-cohesive gold.

The parallelograms in both the Black and Woodbury sets have the face rounded in the long dimension, rather than flat. This rounded form is to prevent the full contact of the face of the plugger at the moment of impact, to prevent chopping of the gold in severe packing and to diminish the danger of fracture of enamel margins. With these instruments, the first impact is on a limited area, but, when this area gives away, the full area of the face is engaged, which thus prevents it from sinking too deeply into the metal or coming too forcibly or suddenly against the enamel margin. Bayonet shaped, strongly contra-angled, or long shank pluggers have a good deal of spring or elasticity in the shank. This will have a tendency to lessen the strength of the blow of the mallet. For this reason, short shank pluggers should be used, and with the bayonet and contra-angle forms additional power should be given the mallet, to overcome the spring of the shank.

Bibliography

1. Ward, Marcus L.: "American Text-book of Operative Dentistry," 6th ed., p. 470.

Black, G. V.: "Operative Dentistry," 6th ed., vol. 2.
Johnson, C. N.: Value of gold foil in modern practice, Jour. Amer. Dent. Assoc., Nov. 1928.
Oman, Carl R.: Gold foil, Jour. Amer. Dent. Assoc., Dec. 1928, p. 2286.
Prime, James Mark: The rationale of gold foil, Dental Cosmos, vol. LXXI, July 1929, p. 691.
Woodbury, C. E., Waters, F. H., Blackwell, R. E. and Southwell, Charles: Symposium on gold foil, Jour. Amer. Dent. Assoc. Feb. 1927, pp. 200–225.

CHAPTER XIX

THE NON-PLASTIC RESTORATIVE MATERIALS (*Continued*)

FILLING OF CAVITIES BY CLASSES—COHESIVE AND NON-COHESIVE GOLD—TIN

GENERAL DIRECTIONS FOR BUILDING COHESIVE GOLD

The Gold.—For students' use, rolls containing 1 grain each are most convenient. These should be cut into eight pieces of 1/8 grains each. This size may be used for general gold building. For filling convenience angles and for use in special locations, the 1/8 grain sections may be cut into halves or quarters containing 1/16 and 1/32 grain respectively. Some operators prefer the cylinders or pellets of similar weights furnished by the manufacturers. Many of the best gold operators prefer to make their own pellets. For this purpose, sheets of number 4 gold are cut into sections containing 1/8, 1/16, 1/32, and even 1/64 of a sheet. A pair of long gold scissors is used, cutting through the paper and the foil at the same time. The pieces are then picked up with a pair of foil carriers, the gold is lightly grasped between the dry thumb, first and second fingers of the left hand, the corners are turned in and the gold rolled into a loose round ball. This procedure makes excellent pellets for filling all types of cavities. When finished, the 64th grain pellets should measure approximately 2 millimeters in diameter; the 32nds, 3½ mm.; the 16ths, 4½ mm. and the 8ths, 7 mm. Some of the manufacturers are willing to make pellets of this form to order, but do not dispense them regularly, on account of the difficulty of preparation.

Annealing.—Use a gold annealer with the flame adjusted to give the correct amount of heat. Too little heat will require longer time and will often not anneal the gold sufficiently to bring out its proper cohesive properties. Too much heat is likely to burn fine edges and make the gold harsh and hard working.

Pluggers.—Use pluggers one-half to one millimeter in size, one-half millimeter, usually, for starting in convenience angles, and larger sizes up to approximately 1 millimeter for building. Correlate the force of the blow to the size of the plugger point and to the conditions and localities being operated on. Automatic pluggers should be so designed that the strength of blow could be adjusted and registered on a dial to correspond to the area of the plugger point being used. The strength of the blow should be increased with bayonet and strongly contra-angled pluggers in operating on mandibular teeth and young teeth with thick peridental membranes. It will have to be diminished for teeth with weakened peridental membranes.

Stepping.—Step the plugger in several definite lines usually parallel with the wall approached. Move it only a distance of three-fourths the diameter of its face, after each thrust or blow. In this way the edges of the blows overlap each other, the gold is "shingled" into place and "bridging" or imperfectly condensed layers are avoided. Usually several lines of steps should be laid down, the first of them being farthest away from the wall approached, the second nearer, and continuing in this manner until the last line is close to the wall.

Condensing.—Lay the gold down in small pieces and thin layers, condensing each layer thoroughly by the stepping process, to assure proper condensation. The amount of condensation necessary will be regulated by the wear and stress to which the filling will be subjected. Fillings exposed to masticating forces require a higher degree of condensation and density than those on labial and buccal surfaces. Contact points, marginal ridges and angles of anterior teeth should be specially well condensed.

Direction of Packing.—Pack in the general direction of the long axis of the tooth, wherever conditions will permit, in order to avoid lateral strain on the fibers of the pericementum and to place the layers of gold in a plane with the plane of the forces of occlusion, so that crushing stress may be resisted to the utmost. This is particularly applicable to Class II and Class IV cavities, and to Class I cavities on occlusal surfaces. In Class II and Class IV cavities, if the layers of gold were laid in the opposite direction, their edges would be exposed to masticatory stresses and the filling would be more likely to break away at the junction of the layers. The line of force applied at right angle to the tooth would also be more likely to stretch the fibers of the pericementum and produce a traumatic pericementitis. In operating in labial and buccal cavities, the direction of force will necessarily have to be largely lateral. Since these cavities have four lateral supporting walls and are not subjected to mastication, the necessity for placing the layers parallel to the long axis of the tooth is of no consequence. However, if too heavy blows are delivered with the mallet in these cases, trauma and tenderness of the tooth may result from excessive lateral strain on the pericementum. Also with Class III cavities the direction of force has of necessity to be changed, since it is impossible to keep it parallel with the long axis of the tooth at all times.

Angle of Force.—In starting the filling and in the early part of the gold building, incline the plugger so that it will bisect point and line angles. In this way the gold is built into the point angles, along the line angles and then spread and condensed equally over the walls uniting to form the angles. Following this and during the building of the rest of the filling, incline the shaft of the plugger from 6 to 12 centigrades away from the lateral walls of the cavity, so that the angle of force will drive the gold ahead of the plugger, toward the wall approached, and prevent the tendency of the gold to buckle up and draw away from the wall.

Wedging.—In packing toward the lateral walls, wedge the last part of the layer being stepped, in between the wall approached and that part of the layer previously condensed, in order that it may be gripped by the natural resilience and elasticity of the dentin. This procedure will assure perfect adaptation to all walls and prevent leakage and later displacement of the filling. All fillings should be placed on the wedging principle. Even with the plastics this general idea should be followed and carried out, in so far as these materials will permit. With cohesive and non-cohesive gold it may be carried out to the highest degree, owing to the force with which these materials may be manipulated.

Contouring.—In proximal cavities build each layer out to full contour as it is laid down, else it will be necessary to later "paste" on gold afterward to restore the contour. This would be a very difficult procedure, owing to the fact that the proximating tooth would obscure the view and prevent the use of proper angles of force. In addition to this, the gold, thus wrongly applied would be likely to chip away later from improper cohesion and condensation, producing a "pitty," irregular or broken surface.

Class III Cavities.—In filling Class III cavities, it is necessary to change the angles of force frequently during the building. The plugging is done somewhat in the arc of a circle, usually packing gingivally, axially, incisally, and again axially, in the order mentioned. In this Class of cavity, with a labial approach, the lingual portion should be kept in advance, so as not to obscure the view, and care should be taken to see that the lingual margin is thoroughly covered as each layer is adapted. If this is not done, it will be very difficult to cover the lingual margin afterward and will necessitate "pasting" the gold on later, the danger of which procedure has been mentioned. The labial portion of the filling is built last. In these cases, if the approach to the cavity is from the lingual aspect, the order of procedure is reversed, keeping the labial portion in advance and finishing on the lingual side. Where the approach, owing to the size of the cavity, may be obtained from either the labial or lingual aspect, either procedure may be followed, to suit the convenience of the operator.

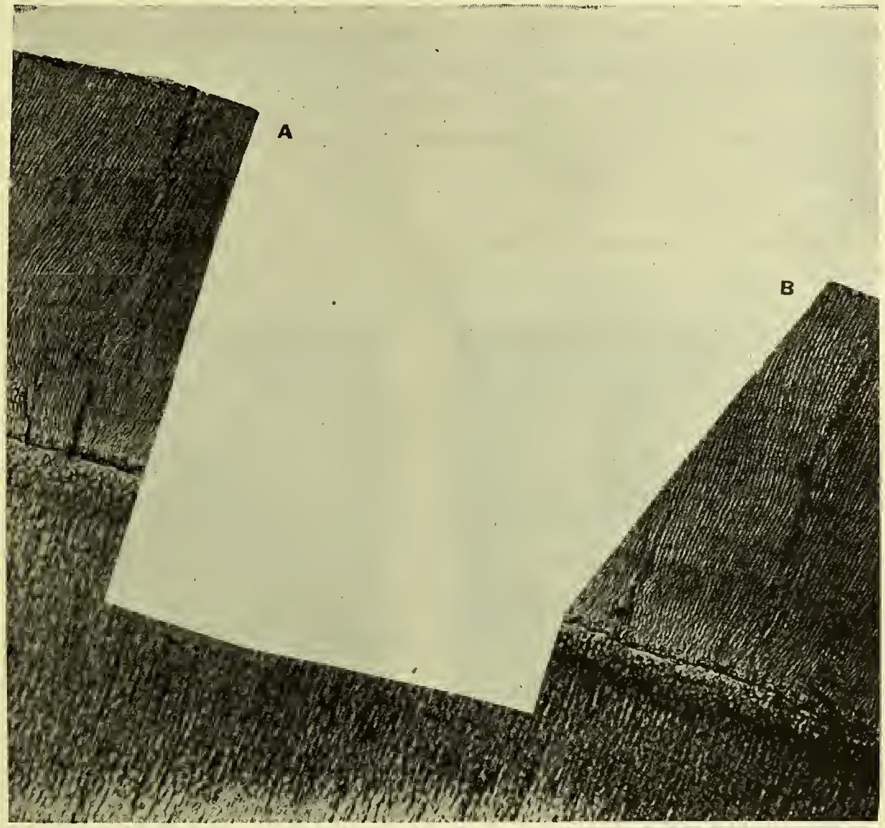


FIG. 523.—Cavity cut into the enamel and dentin. The enamel wall marked A, follows the direction of the enamel rods, has not been bevelled and is mechanically weak. The wall marked B, has been properly bevelled its entire thickness, is mechanically strong and shows correct preparation. The margin at A could be easily fractured during the condensation of gold against it or later from the stresses of mastication. That at B would not be so readily fractured since it does not present the sharp angle seen at A and will be later protected by the gold after it has been covered. (From G. V. Black's Operative Dentistry.)

The Cavo-surface Angle.—Cover the margin with several layers of gold by means of hand pressure, before condensing with the mallet, to avoid the danger of fracture of the enamel. Enamel margins are easily fractured by too heavy blows of the mallet, the careless use of foot pluggers, or failure to interpose sufficient gold before impact of the blow. In some instances it will be better practice to leave the gold covering certain margins partially condensed, until completion of the filling, when after-condensation of these areas may be given special attention. If this procedure is practiced, care should be observed to see that a sufficient body of gold is laid down over the margin during the building process to insure perfect covering and adaptation, else difficulty may be experienced later in adding the necessary quantity. Fig. 523.

Restoring Anatomical Form.—Occlusal surfaces should be built up to properly restore the various anatomical markings, including marginal ridges, grooves, fossae, transverse and triangular ridges. Sufficient gold should be built on these localities and on all surfaces of the other classes of cavities to allow for the removal of an adequate amount during the finishing operation to secure a good polish. Contact points should be built out sufficiently to allow for later finishing down and should be especially well condensed with heavy blows of the mallet. The gold should be well built up in the neighborhood of the marginal ridges on posterior teeth and axial line angles in proximal fillings in anterior teeth, so that these may be properly restored in the finished filling. Figs. 524 and 525.

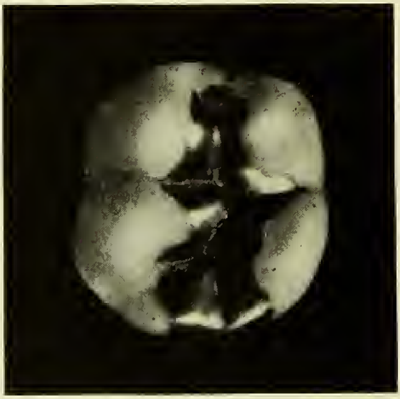


Fig. 524.—Restoration of anatomical form. Proximo-occlusal gold restoration on a lower second molar.

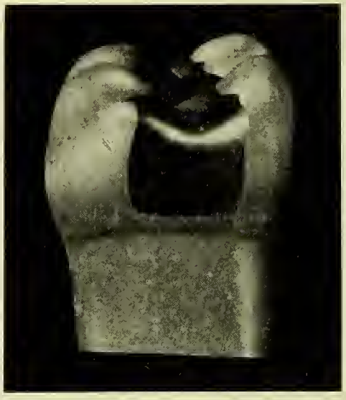


Fig. 525.—Proximo-occlusal gold filling on a lower second molar.

Securing Adequate Condensation.—The entire filling should be as nearly as possible perfectly condensed throughout from the first piece to the last, to secure uniformity of density and to avoid "bridging" and pitted surfaces. The condensation should have a minimum density or specific gravity of 15. Eighteen is often desirable and readily obtainable.

By "bridging" is meant the formation of air spaces or pits in the filling, due to faulty manipulation incident to (*a*) imperfect "stepping;" (*b*) inadequate malleting, resulting in failure of the gold to reach the bottom of the indentations made by the pyramids of the serrated plugger point; or (*c*) the injudicious changing of plugger points.

If the student is not sure of perfect condensation throughout and on the surface, the entire filling may be gone over with heavy blows of the mallet after it has been built to form. However, if proper condensation has been practiced during the building, this should not be necessary. Too much reliance should not be placed in this procedure, since surface condensation cannot remedy imperfect condensation in the body of the filling.

COHESIVE GOLD RESTORATIONS IN CAVITIES BY CLASSES

Class II Cavities

The method of filling a mesio-occlusal cavity in a bicuspid will serve to illustrate the technic of filling all Class II cavities with cohesive gold. The rubber dam should be in position, the gold annealed and all the necessary instruments sterilized and placed on the tray ready for use. The instruments used are the foil pliers or carriers, holding instrument, round pluggers 5-10-3, 7½-10-3, and parallelograms 10-5-3-3, 5-10-3-3, 12-6-6-10, and 6-12-6-10. See Figs. 521 and 522.

The Gingival and Proximal Portions.—1. First, take up a small piece of gold, and carry it by means of the foil carrier into the most convenient gingival point angle, holding it in position with a gold holder in the left hand. Fig. 526.

2. Condense thoroughly with hand pressure, by means of a 5-10-3 gold plugger, directed equally toward the three walls forming the point angle, continuing to hold in position with the gold holder until the point angle is filled. Fig. 527.

3. Now, with the same plugger, or with the 7½-10-3, build the gold along the connecting line angle (gingivo-axial), condensing equally against the two walls which form the line angle by bisecting it with the plugger. Now, still holding the gold securely in position with the gold holder, anchor it into the opposite point angle, when it will then be mechanically held in place by the form of the cavity and the bar of gold extending along the line angle and into the point angles. The gold holder may now be discarded. Fig. 528.

4. Now, changing to a three-quarter millimeter plugger or the 10-5-3-3 and 5-10-3-3, depending on the size and accessibility of the cavity, condense thoroughly with the hand mallet, or other form of mallet, using 15 pounds pressure and continuing to bisect the angle.

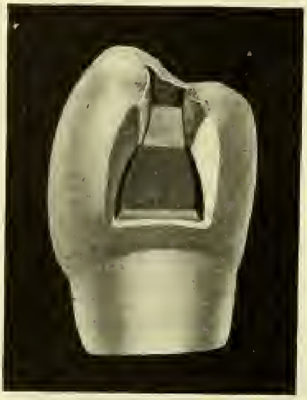


FIG. 526.—Cavity preparation for gold in a lower second bicuspid.

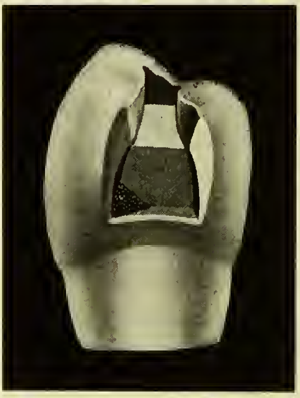


FIG. 527.—The bucco-axio-gingival point angle filled.

5. Now build up a heavy triangular bar of gold along the axio-gingival line angle, using mallet force with the 10-5-3-3 plugger, the angle of force being 12 centigrades away from the axial wall of the cavity, in order to bisect the angle formed by this and the gingival wall. The gold should be extended about equally over the axial and gingival

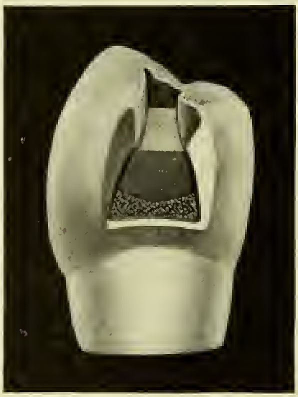


FIG. 528.—Bar of gold built from the bucco-axio-gingival point angle, along the axio-gingival line angle into the opposite point angle. The bar has been strengthened with additional gold.

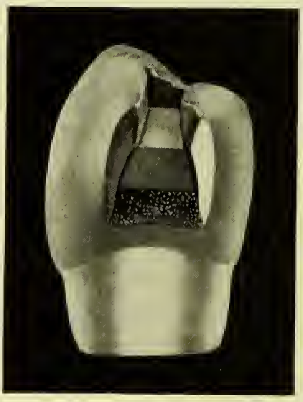


FIG. 529.—The gingival and part of the axial wall are covered.

walls, continuing in this manner until the gingival wall is covered and the gold extends well up against the axial wall. Fig. 529. The plugger should be systematically stepped and, as the buccal and lingual walls are approached, the plugger should be inclined 6 centigrades away from each, continuing also to bisect the angle formed by the axial and gingival walls. In some instances, depending on the approach to the work, the 10-5-3-3 plugger may be changed to the 5-10-3-3 (hoe shape), turning it laterally with its longer diameter facing mesio-distally. Often, the larger pair of parallelograms, 12-6-6-10 and 6-12-6-10 will be found more convenient in molars. In no case should a thin layer of gold be spread over the gingival wall, but the building should gradually proceed from the triangular bar in slowly increasing amounts equally up the axial wall and over the gingival wall to the gingival cavo-surface angle, which should now be carefully covered, avoiding fracturing it by interposing sufficient gold and not bringing the direct force of the blow in contact with it. The gingival cavo-surface angle should be thoroughly and perfectly covered at this time, or it will be impossible to properly do so later.

6. Now, with the parallelograms, used with heavy mallet force, build on to the portion of gold previously laid over the gingival margin until the entire body of gold previously built is level and its surface is on a horizontal plane with the gingival wall. Fig. 530.

7. Next, the entire proximal portion is built in regular laminae, by the stepping process, using the parallelograms, carrying it up to a level with the step portion of the cavity. As each lamina is laid on, it should be built out to full contour and also well over the buccal and lingual cavo-surface angles, since it will be impossible to properly add gold later. Condensation of the gold should be accomplished by stepping several lines of steps from the center of the mass of gold toward the buccal wall and repeating the same procedure toward the lingual wall. The lines of steps should run mesio-distally, in a direction parallel with the buccal and lingual walls. The last line of steps should wedge the gold against these walls, and each line laid down should also wedge it against the axial wall. Fig. 531.

The Occlusal Portion.—8. Building into the occlusal step should now be started. Several methods of accomplishing this may be resorted to, depending on the inclination of the tooth, whether the tooth is an upper or lower, and on the line of approach. (1) Frequently it will be better to start the gold in the disto-bucco-pulpal point angle in the extremity of the step, build a triangular bar along the disto-pulpal angle across to the disto-linguo-pulpal point angle and anchor it in position as a separate mass from the main body of the filling; or the procedure may be reversed, starting in the disto-linguo-pulpal point angle and building across to the disto-bucco-pulpal point angle. Whichever procedure is most convenient should be followed. Fig. 532. Then, with this as a starting point, a triangular bar may be built from it along the bucco-pulpal line angle over to the proximal portion previously built and united to it. Then another triangular bar is built in the same manner along the linguo-pulpal line angle and united to the proximal portion of the filling; or the procedure may be reversed, first building the linguo-pulpal triangular bar and then the bucco-pulpal triangular bar, depending on convenience of the operator. (2) Occasionally the gold may be started in the disto-linguo-pulpal point angle, built in triangular bar form along the linguo-pulpal line angle over to the main body of gold in the proximal part; or if more convenient, it may be first started in the disto-bucco-pulpal point angle and a bucco-pulpal triangular bar be built. Following this, a triangular bar is built along the disto-pulpal line angle, another along either the bucco-pulpal or linguo-pulpal line angle until all three angles are covered and the entire portion of gold in the step united to the proximal portion. (3) In some instances it may be preferred to start the gold on the top of the proximal portion first built, then construct a linguo-pulpal triangular bar, then a mesio-

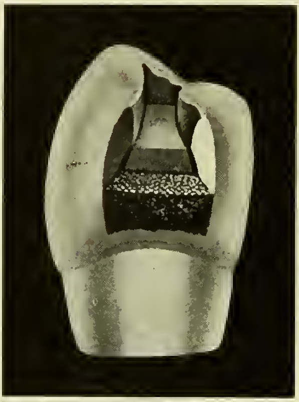


Fig. 530.—The gold has been levelled up and carried half way to the top of the step.

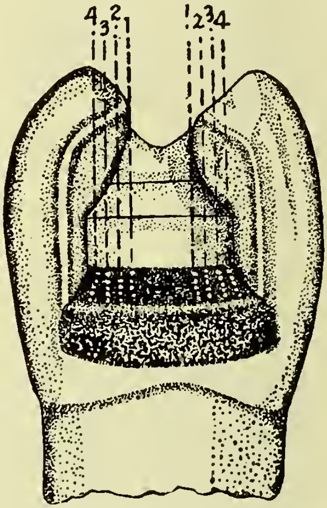


Fig. 531.—Stepping the gold. The numbers indicate rows of steps in sequence, progressing toward the lateral walls.

pulpal and finally a bucco-pulpal bar; or to start in the same manner, constructing the bucco-pulpal bar first. The angle of approach and convenience of the operator will regulate the order of procedure.

Usually, the first of the methods mentioned will be preferred for starting the gold in the step. However, either may be used, depending on convenience and experience of the operator. In either case, the same general principles of technic are followed as described for building the gingivo-axial triangular bar. Start the gold in a point angle and build across the line angle into the opposite point angle with the 5-10-3 plugger by means of hand pressure. Then condense with the mallet, change to the 7½-10-3 or the parallelograms, add more and more gold, building equally over the lateral and pulpal walls until strong triangular bars are built. In doing this always bisect the angles formed by the uniting walls. This is continued until the proximal portion of the filling is well overlapped and the two parts of the filling are securely united.

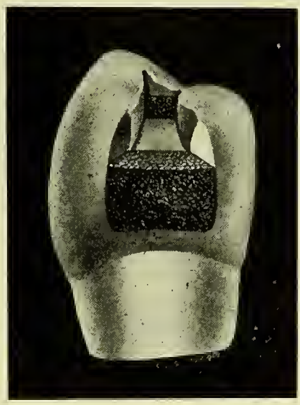


FIG. 532.—The gold has been built to the top of the step, and the occlusal portion started at the extremity of the step.

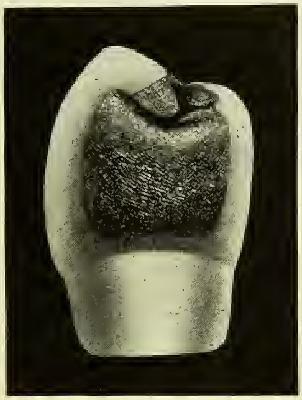


FIG. 533.—Gold-building complete and ready for finishing.

Completing the Filling.—9. Now the rest of the occlusal portion of the filling, the contact point, the remainder of the proximal portion and the marginal ridge should be built. Fig. 533. This is done with plugger 10-10-3 and the parallelograms. The remainder of the pulpal wall is covered and levelled up, the gold is built up over the cavo-surface angles, the contact point is strongly built out against the proximating tooth and the occlusal form is restored. The separator should be in position and the gold built out strongly against the proximating tooth in the location where the contact point is to be restored. When this point is reached, it will often be advisable to slightly tighten the separator to gain additional separation, to change to a smaller plugger and to heavily condense the gold which is to provide the contact point. Build it out tightly against the proximating tooth in the same manner that gold is wedged against cavity walls. In building against lateral walls, use the parallelograms with one of the flat sides parallel with the cavity wall and wedge the last layer of steps well against the walls. In covering the cavo-surface angles, be sure to first place sufficient gold and then to prevent direct impact of the plugger, with probable fracture of enamel.

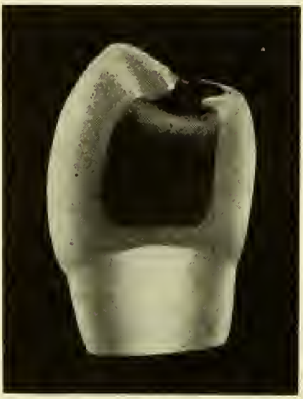


FIG. 534.—Finished restoration.

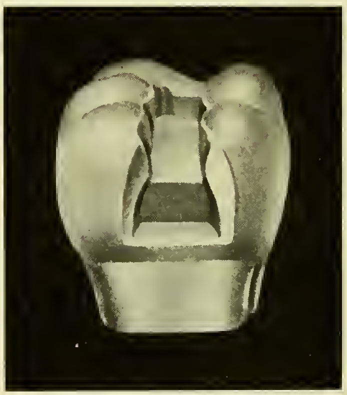


FIG. 535.—Cavity preparation for Class II gold filling on a lower first molar.

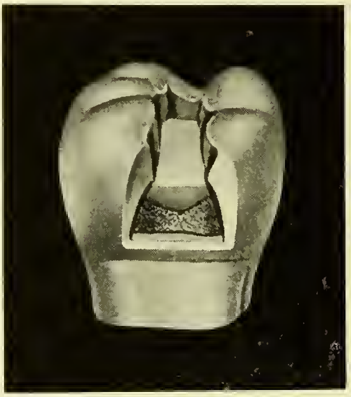


FIG. 536.—Bar of gold built into gingival point angles and across gingivo-axial line angle.

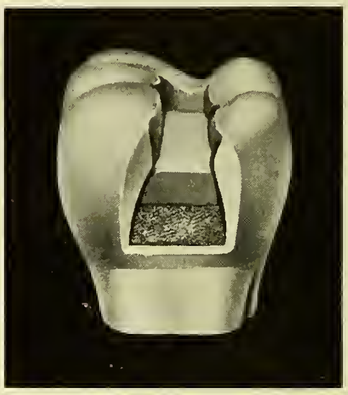


FIG. 537.—Gingival and part of the axial wall covered.

A slight excess of gold should be built in every part to allow for subsequent finishing down, when the entire surface may receive a final malleting, if desired, to produce further hardening. This after condensation may be accomplished along buccal, lingual and gingival margins with the foot pluggers 20-5-2-18, 15-5-5-12, 15-5-3-18, or with direct action quadrangles, when direct blows may be delivered. Fig. 534.

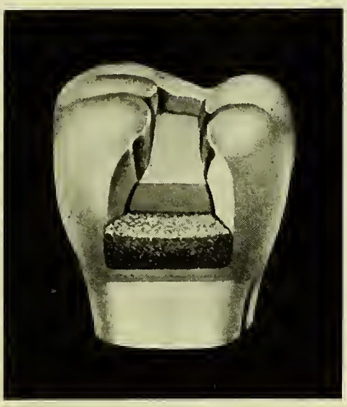


FIG. 538.—Gold levelled up.

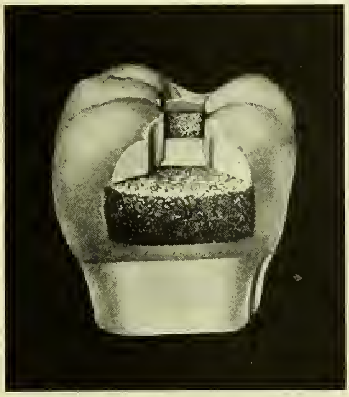


FIG. 539.—Gold built to top of step and occlusal part started at extremity of step.

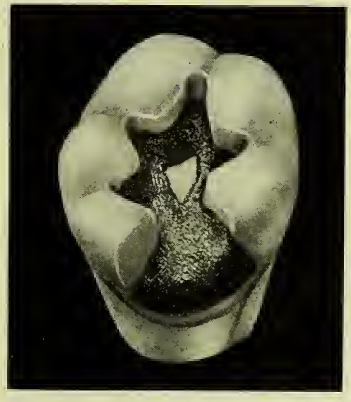


FIG. 540.—Triangular bars of gold built over the pulpal line angles and united to the proximal portion.

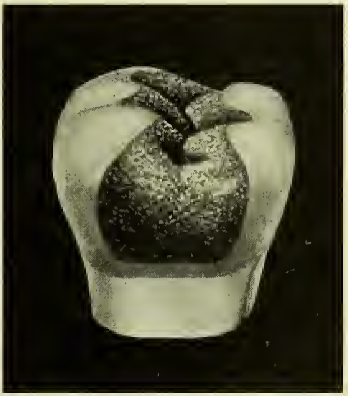


FIG. 541.—Restoration of anatomical form and completion of gold building.

The two additional series, Figs. 535 to 543 and Figs. 544 to 550 further illustrate the various steps in building Class II gold restorations.

Disto-occlusal Cavities.—In filling disto-occlusal cavities, it is often difficult to obtain proper angles of force with direct action pluggers.

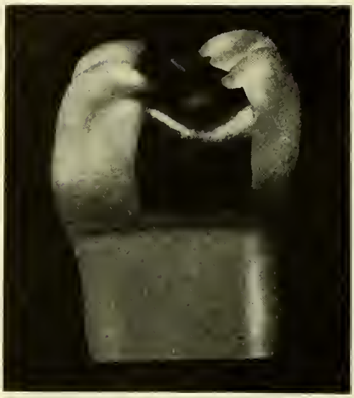


FIG. 542.—Proximal view of completed filling.

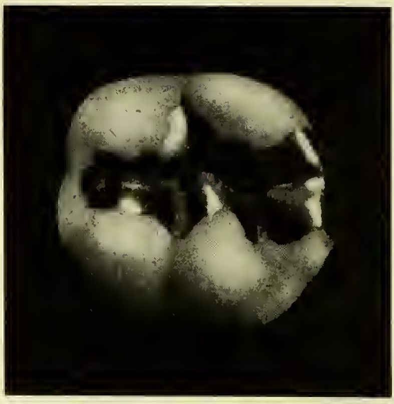


FIG. 543.—Occlusal view.

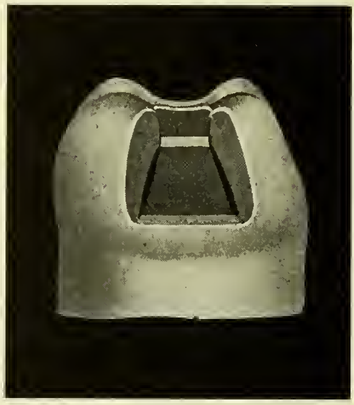


FIG. 544.—Cavity preparation for Class II gold filling in an upper molar.

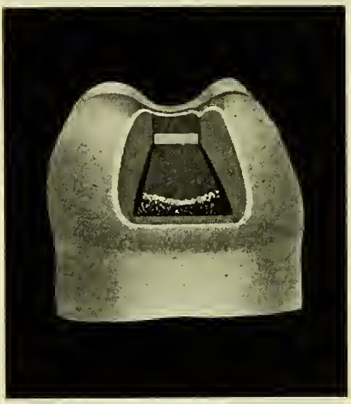


FIG. 545.—Triangular bar built.

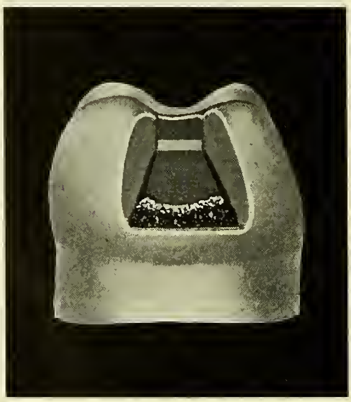


FIG. 546.—Part of gingival and axial walls covered.

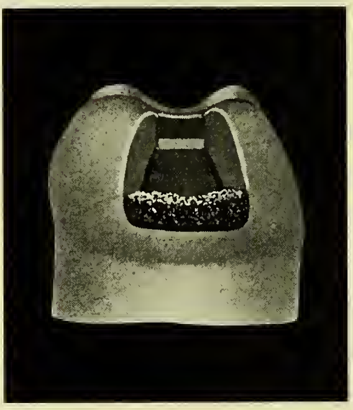


FIG. 547.—Levelling up the gold on the gingival wall.

For this reason, gold inlays are frequently the alternative in cavities of this type. On upper teeth the difficulty is not so great and disto-occlusal cavities may often be readily reached in upper bicuspids and even in first molars. In these cavities, often an approach from the disto-buccal side may be obtained. No attempt should be made to build gold with mallet force against a wall in which a direct angle of force cannot be obtained. Sometimes hand pressure must be used. In other cases, the back-action pluggers of the Black, Woodbury, or Abbott sets, seen in Figs. 519, 520 and 521 will be indicated. This is particularly the case in disto-occlusal cavities in lower bicuspids and molars.

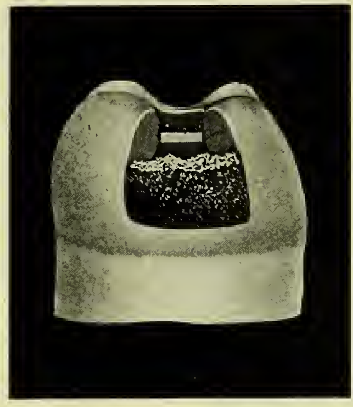


FIG. 548.—Gingival and middle thirds of proximal portion built and triangular bar built at extremity of step.

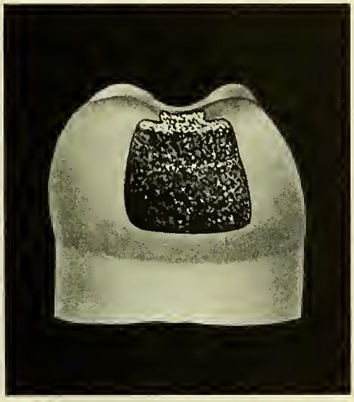


FIG. 549.—Filling built.

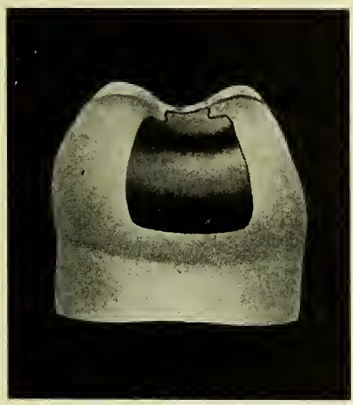


FIG. 550.—Filling polished.

Class I Cavities

The filling of Class I cavities is so similar to the technic described for the occlusal part of Class II cavities that its description may be much abbreviated. Figs. 551, 552 and 553. These are the easiest cavities to fill with cohesive gold. In occlusal cavities in molars the access may often be much improved by extending the mesial or buccal or both walls on a slope toward these margins to improve the angle of force of the pluggers. This is a convenience form. Cross-mouth positions will often be valuable, especially for lower molars, to secure proper angle of force.

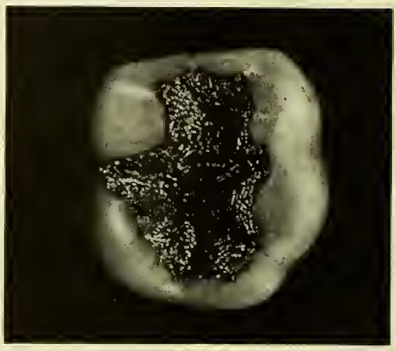


FIG. 551.—Class I gold filling. Gold condensed, but not polished.

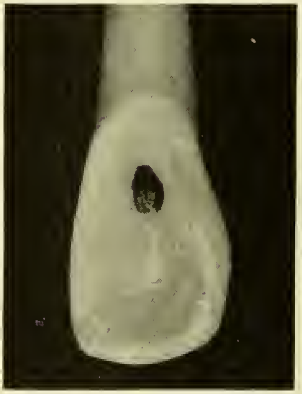


FIG. 552.—Filling in lingual pit of upper lateral.

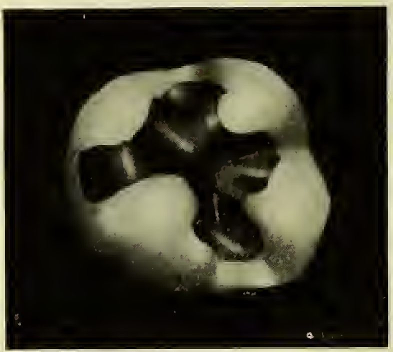


FIG. 553.—Gold filling involving mesial and distal fossae and lingual groove on upper molar.

The filling may be started in a convenience angle in the distal portion of the cavity and a triangular bar built across the line angle here, using pluggers 5-10-3, 7½-10-3, and the parallelograms. All line angles should

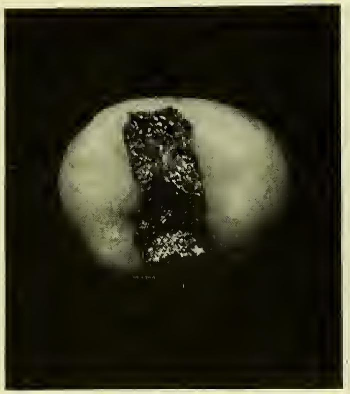


FIG. 554.—Unpolished gold filling on occlusal surface of an upper bicuspid.

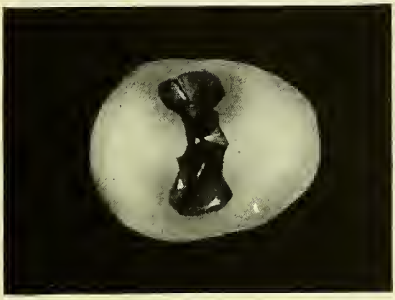


FIG. 555.—Finished filling on upper bicuspid.

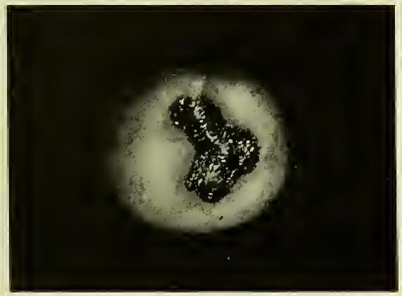


FIG. 556.—Unpolished filling on occlusal surface of lower second bicuspid.

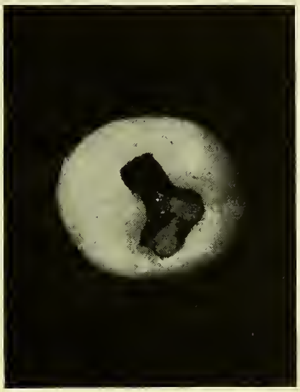


FIG. 557.—Finished filling on lower second bicuspid.

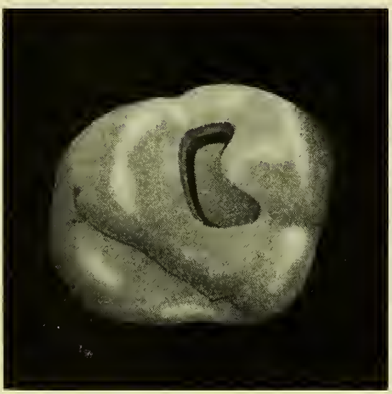


FIG. 558.—Cavity preparation in central fossa of upper molar.

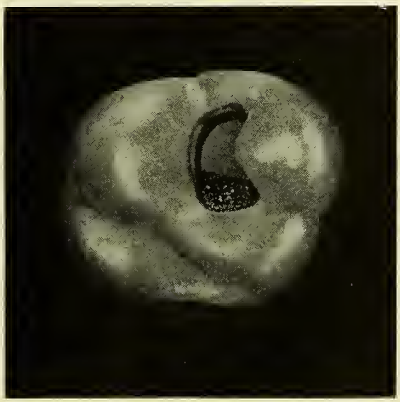


FIG. 559.—The gold anchored.

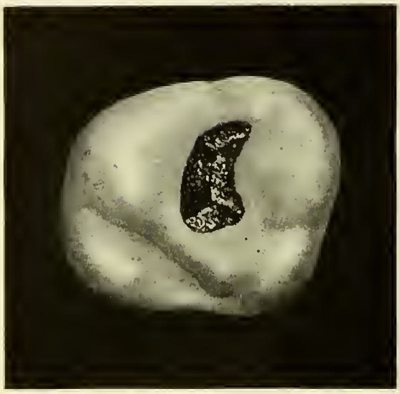


FIG. 560.—Gold building complete.

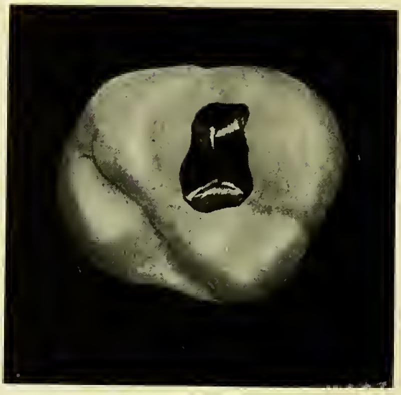


FIG. 561.—Filling finished.

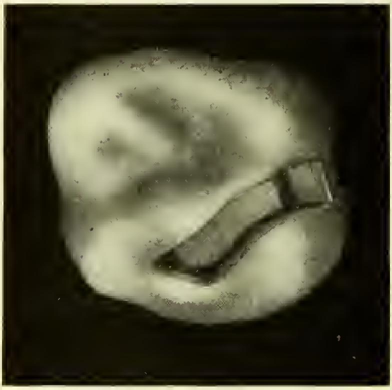


FIG. 562.—Cavity involving distal fossa and lingual groove of upper molar (step form.)

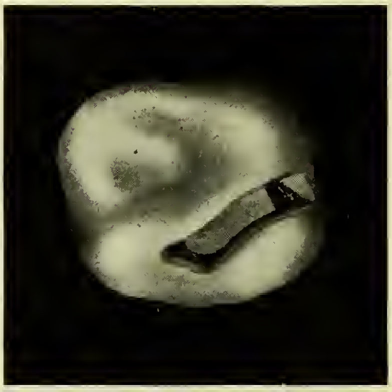


FIG. 563.—Gold anchored in the step.

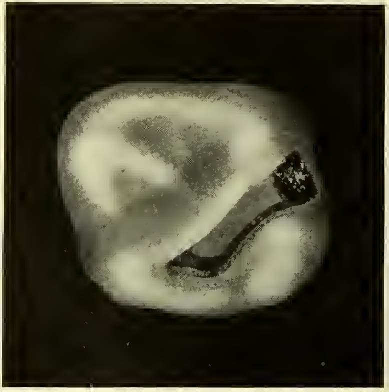


FIG. 564.—Progress in gold building.

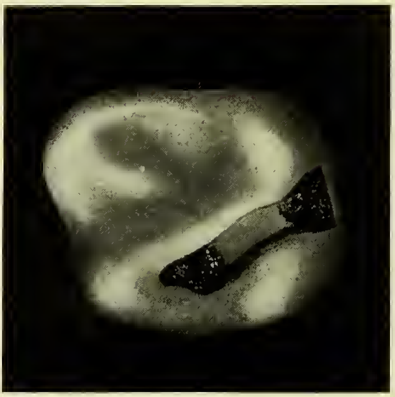


FIG. 565.—Gold built into step and anchored at other extremity of cavity.

be bisected, as previously described, and the gold should be stepped and securely wedged against the lateral walls with the parallelograms. If proper angle of force cannot be obtained for wedging against the mesial or other wall, hand pressure or a reverse action plugger with the mallet must be used. Pit and fissure cavities on buccal or lingual surfaces are filled in the same manner, the technic being the same with such modifications as are necessary to secure proper approach and angle of force. See Figs. 554, 555, 556, 557, and 558 to 567 inclusive.

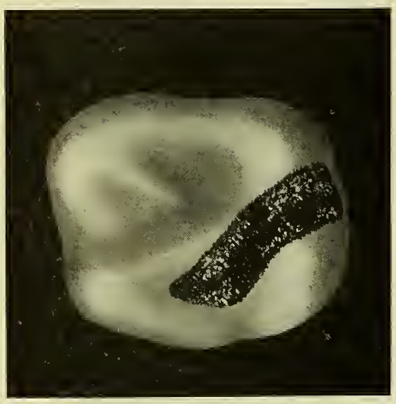


FIG. 566.—Margins covered and gold building completed.

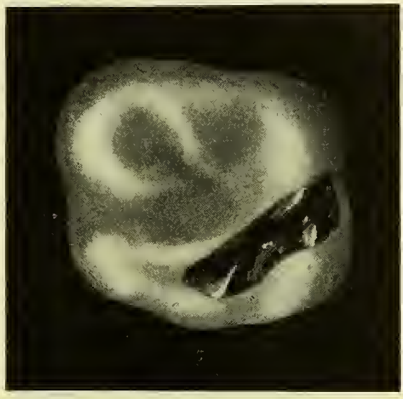


FIG. 567.—Filling polished.

Class V Cavities

Gingival third cavities are filled on the same general principles as are pit and fissure cavities. Those located on labial surfaces and the buccal surfaces of bicuspids are easily reached and filled. The gold is started in a convenience angle in the distal part of the cavity, condensing along a line angle, to the adjacent point angle, and anchored into position. The angles of force should be properly obtained, bisecting the line angles and securely wedging the gold against lateral walls. In no case should a thin layer of gold be built across the axial wall in these cavities, or across the floor of Class I cavities, but rather it should first be built and wedged securely against the lateral walls and the center of the filling levelled up later. Class V cavities in second and third molars often seem difficult, on account of the angle of approach. Special care must be taken to securely wedge the gold against the occlusal and mesial walls. A part of this procedure will often have to be accomplished with hand pressure by means of the right angle pluggers 5-1-23 or 5-2-23. The use of the

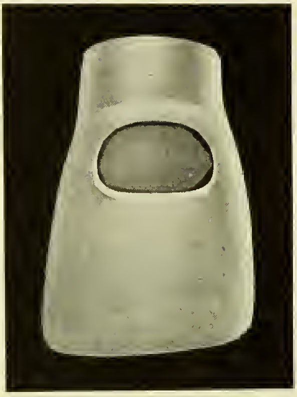


FIG. 568.—Class V cavity in an upper central incisor.

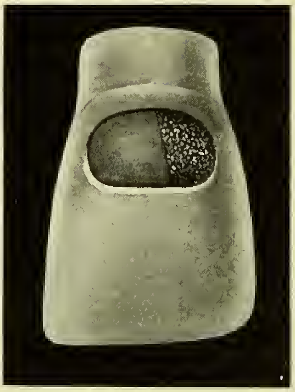


FIG. 569.—Gold anchored in the point angles in the distal part of the cavity and built along the connecting line angle.

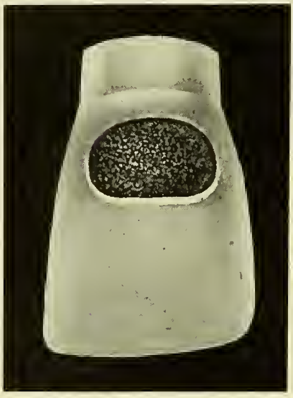


FIG. 570.—Line angles and lateral walls covered and gold leveled up in the center.

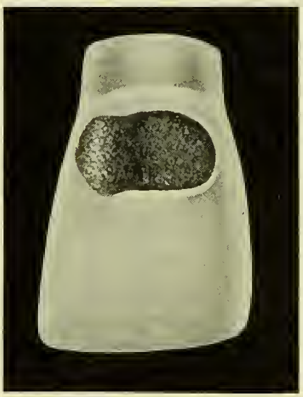


FIG. 571.—Covering the margins.

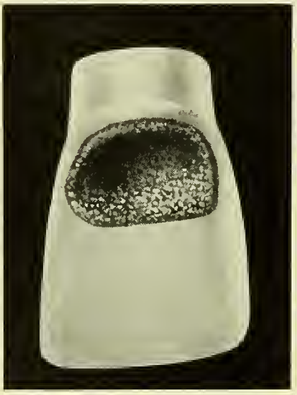


FIG. 572.—Margins covered.

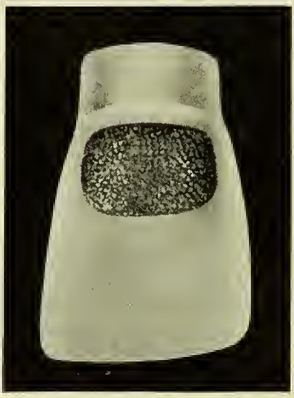


FIG. 573.—Center levelled up and gold building completed.

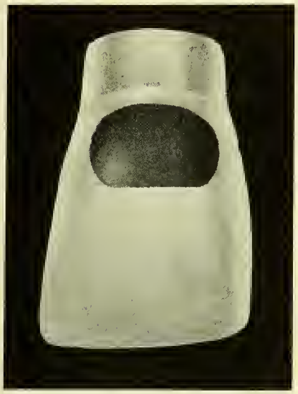


FIG. 574.—Filling polished.

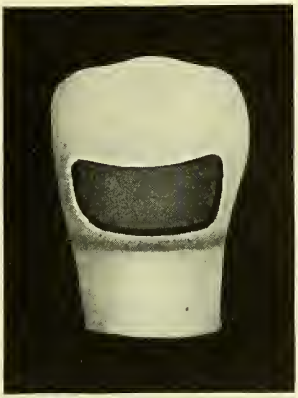


FIG. 575.—Class V preparation on lower bicuspid.

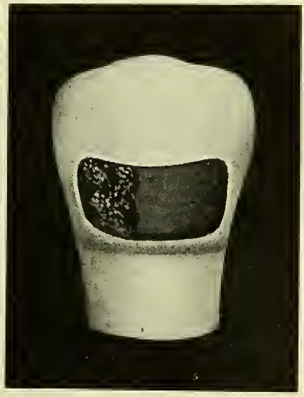


FIG. 576.—Gold anchored and building progressing mesially.

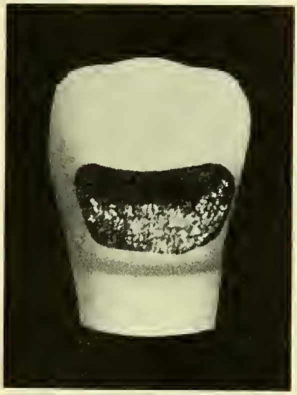


FIG. 577.—Margins covered.

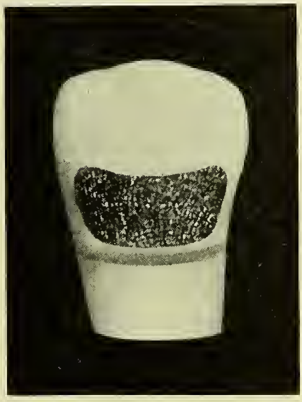


FIG. 578.—Condensation complete.

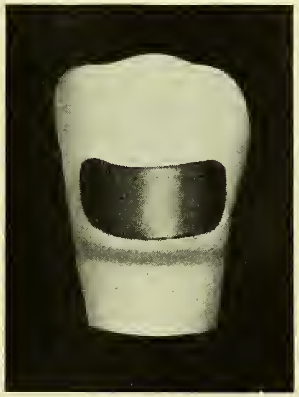


FIG. 579.—Filling polished.

cervical clamp is usually indicated in these cavities. See Figs. 568 to 579 inclusive.

Class III Cavities

The instruments used for filling Class III cavities are the gold carriers, the assistant plugger for holding the gold in position until it is anchored; 5-10-3 or 7½-10-3 round pluggers for starting the gold; 5-10-3-3 and 10-5-3-3 parallelograms for general gold building; the foot pluggers 20-5-2-18 or 15-5-2-18 for condensation against the lingual wall and margin; the right angles 5-1-23 or 5-2-23 for filling the incisal retention; the bayonets 5-1-0 or 7½-3-0 for wedging against the labial wall. The most important consideration in filling these cavities is the use of the correct angles of force. If these are observed in proper order and the correct instruments used in applying them, the operation is comparatively simple; otherwise, it becomes a very difficult procedure. In ordinary cases, the labial approach will be used, since this is the most convenient and the least difficult. Occasionally, where it is necessary or advisable to preserve much of the labial plate and also in smaller size cavities, the lingual wall will previously have been extended on to the lingual surface and the approach will have to be made from the lingual aspect. Much of the work is then done with the use of the mouth mirror, the order of building being reversed. A case with labial approach will first be described. See Figs. 581 to 586.

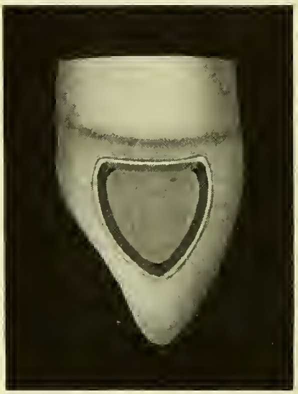


FIG. 580.—Class III cavity preparation for gold.

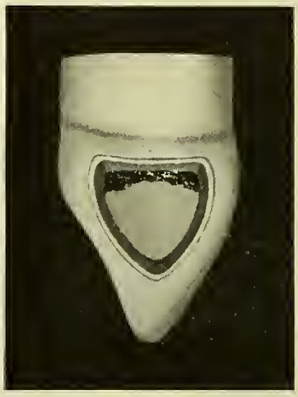


FIG. 581.—Gingival point angles filled and triangular bar built across gingivo-axial line angle.

1. Anchoring the Gold.—With the gold carriers place a small piece of gold in the linguo-axio-gingival point angle and hold it in position with the gold holder in the left hand. Now change to a 5-10-3 plugger and with the right hand condense into the point angle, using hand pressure. Add additional pieces of gold and condense in the same manner with hand pressure until the point angle is filled, using the same plugger and continuing to hold the gold in position with the gold holder or assistant plugger. The latter may be entered into the cavity from the lingual or labial side, whichever is more convenient. With this size plugger only three and one-half pounds pressure will be required to thoroughly condense the gold. As each layer is condensed, three

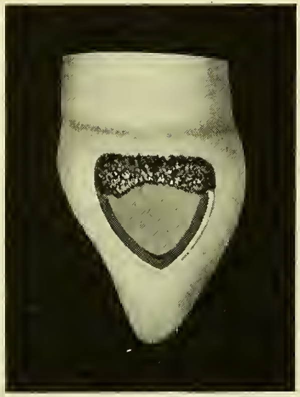


FIG. 582.—Gingival wall and margin covered and gingival portion built out to full contour.

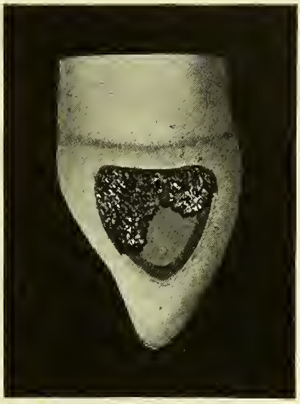


FIG. 583.—Plugging from the labial approach and covering the lingual wall and margin.

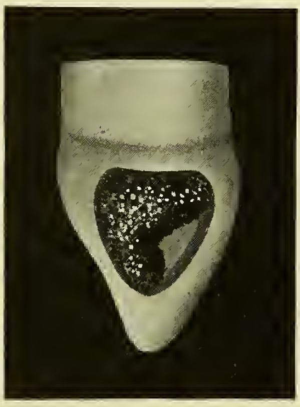


FIG. 584.—Lingual portion complete and incisal angle filled. Gold built to full contour.

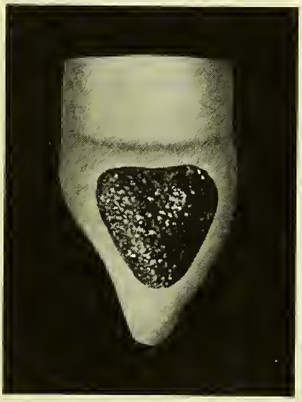


FIG. 585.—Labial portion filled and gold building completed.

rows of steps should be run from the labial approach toward the point angle, holding the plugger in such a position that it will bisect the point angle. The first row should run along the axio-gingival line angle into the point angle; the second row is run parallel with it along the gingival wall into the point angle; and the third in the same manner on the axial wall.

2. Building the Triangular Bar.—Holding the gold in position with the assistant gold plugger, add additional pieces to the foundation already built, carrying them along the gingivo-axial line angle and finally anchoring them into the labio-axio-gingival point angle. For this purpose use the same plugger as before, with hand pressure. In laying the gold along the line angle the plugger should bisect it, but its shaft should be inclined slightly more toward the gingival wall. In this way the gold should be built up over the axial wall to a greater extent than over the gingival wall. A line of steps should be first run along the line angle, then one or two over the gingival, and several over the axial wall. In filling the labio-axio-gingival point angle, the 5-10-3 plugger is entered from the lingual side, the direction of force is changed, bisecting that point angle and filling it in a similar manner as described for filling the linguo-axio-gingival angle. If more convenient, bayonet plugger 5-1-0 or 7½-3-0 may be used for filling this latter angle, inserting it from the labial aspect. If preferred, the two point angles may first be filled separately and then the triangular bar built across from lingual to labial and uniting them. In either case, mallet pressure should be now applied with the 5-10-3, 7½-10-3 or the parallelogram plugger and the foundation thoroughly condensed. Figs. 587 and 588.

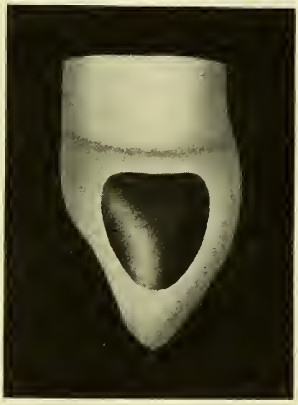


FIG. 586.—Filling polished.

3. **Covering the Gingival Wall and Margin.**—Now with the 7½-10-3 or parallelogram 5-10-3-3 plugger, continue to build the gold on to the axial and gingival walls, stepping and bisecting the angle as before until the gingival wall and cavo-surface angle are covered.

4. **Building the Lingual Portion.**—With the exception of the filling of the incisal point angle, the rest of the building is done with mallet force. With the parallelogram pluggers or Woodbury foot plugger number 9, entered from the labial side, condense gold at the linguo-gingival portion on to the foundation previously built. Build it up in triangular form and cover the cavo-surface angle at this point. The lines of stepping begin on the foundation and extend toward the linguo-gingival cavo-surface angle. The plugger is now entered from the lingual side, the direction of force reversed and the gold is condensed over the linguo-gingival margin. Now build the gold along the lingual wall in a gradually increasing triangular form, the base of which is the foundation, the apex pointing along the lingual wall toward the incisal wall. As this building along the lingual wall progresses, more gold is added on the gingival and axial walls to strengthen the triangle. The malleting should be done first from the labial approach, then the gold should be condensed over the lingual margin from the lingual approach. The laminae of gold should be built out to full contour on the lingual side as the building progresses, to restore the lingual marginal ridge. As the gold progresses toward the incisal point angle, gold may be gradually built on to the foundation at the labio-gingival angle. The building is thus continued in the arc of a circle, the lines of force being

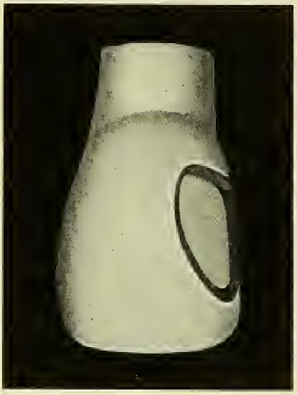


FIG. 587.—Class III cavity in which the labial plate of enamel has been involved by caries.

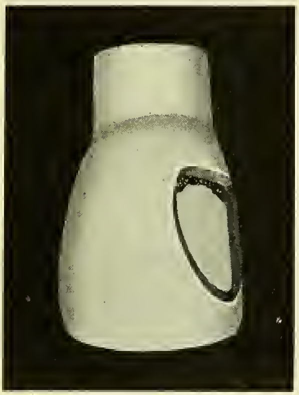


FIG. 588.—Labial approach. The gingival point angles filled and the triangular bar being built.

directed toward the lingual, the gingival, and the labial, but inclined also against the axial walls. During the progress of this building it will frequently be necessary to mallet the gold from the lingual approach with the Woodbury foot plugger number 9 or one of the foot pluggers of the Black set previously mentioned. Avoid building too much gold over the axial wall at this time, else the view of the work will be obscured. Observing the gold from the labial view, it should now be flat or concave labio-lingually. Fig. 589.

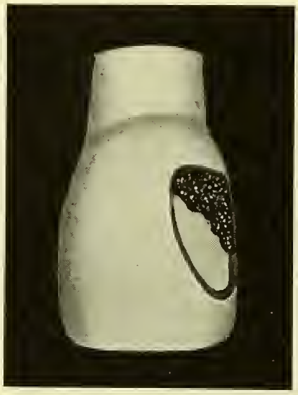


FIG. 589.—Covering the gingival and lingual walls and margins.

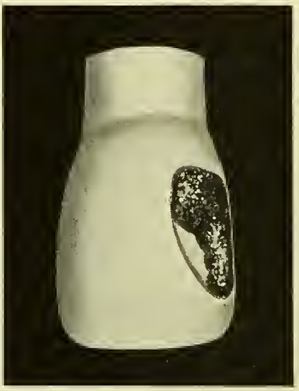


FIG. 590.—Gingival and lingual portions built and incisal angle filled.

5. Filling the Incisal Portion.—When the gold has been built nearly to the incisal anchorage, this should be filled separately with the right angle pluggers 5-1-23 or 5-2-23, using hand pressure. As soon as this retention is solidly filled, more gold is malleted on to the body of the filling along the lingual wall, united to that placed in the incisal retention and then malleted against the incisal portion of the labial wall, so as to wedge it forcibly into these areas and securely grip the entire filling into position. At the same time, additional gold is also added to the gold previously condensed at the labio-gingival angle and margin. This leaves the central part of the labial wall still unfilled. The building of the incisal part of the filling is still in the arc of a circle, the angles of force being directed toward the lingual, then the incisal, then the labial walls. Frequently several instruments will be used in rapid succession in this part of the work, viz. the right angle plugger 5-1-23 or 5-2-23 for filling the incisal retention, the 5-10-3-3 parallelogram or Woodbury

No. 9 for wedging against the lingual wall and the 5-1-0 or 7½-3-0 bayonet for plugging against the labial wall. Also the foot plugger for covering the cavo-surface angle of the lingual margin will frequently be needed, using it from the lingual side. Fig. 590.

6. Building the Contact Point.—At the same time that the procedures incident to the building of the incisal portion of the filling, described in the previous paragraph, are in progress, the contact point must be restored. This is accomplished by wedging the gold tightly against the proximating tooth in the proper location for the contact point, as each layer is added. This wedging process should be directed in such a manner that the proximating teeth are forced slightly apart, in order that the contact point may be built slightly over full, in order to restore the mesio-distal diameter of the tooth, and to allow the necessary excess gold for finishing down later. If the separator is in position, it may be slightly tightened at this time. The contact point should receive special malleting to secure the necessary hardness and density.

7. Covering the Labial Wall and Margin.—With the parallelogram 5-10-3-3 or a bayonet 5-1-0 or 7½-3-0, the central part of the labial wall and margin, which has been left uncovered, should now be filled. This is done by directing the angle of force toward the labial wall, laying down a series of steps running with this wall and wedging the gold securely into place. The labial contour should be fully restored and sufficient gold added to perfectly cover the margin and to build up the line angle uniting the labial and proximal surface. Esthetics demand the restoration of this line angle and the meso-distal diameter of the tooth. Utility and restoration of function demand restoration of the lingual marginal ridge.

Many of the western operators who use the hand mallet exclusively, vary or modify the cavity preparation and the procedure herewith described for filling Class III cavities. In general, these modifications consist of leaving the labial part of the gingival wall and the entire labial wall unfilled until near the end of the operation. This affords additional space and a better view of the work during the building of the lingual portion and the contact point. In this technic the angles of force are directed largely against the lingual and axial walls, and later against the incisal wall when this part of the gold is being built. The entire labial portion is then built as the final procedure in the work, the angle of force being directed toward the labial wall. These modifications are fully described by Dr. Charles E. Woodbury in his work entitled

"The Making and Filling of Cavities in the Proximal Surface of the Front Teeth with Gold Foil."

Lingual Approach.—In filling Class III cavities with a lingual approach, the procedures just described are reversed. The labio-gingivo-axial point angle is first filled, the triangular bar is built, the gingival wall and margin are then covered, the labial wall is built, the incisal retention is filled and the filling finished on the lingual, rather than on the labial wall. In larger cavities with both labial and lingual approach, the filling may be built in either manner preferred, to suit the convenience of the operator. Figs. 591 to 599.

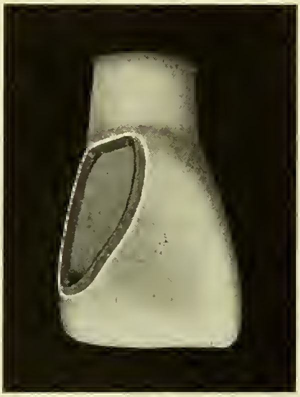


FIG. 591.—Class III cavity with lingual approach.

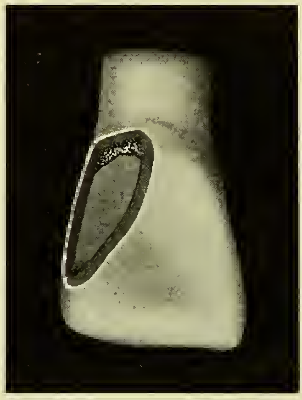


FIG. 592.—Triangular bar being built.

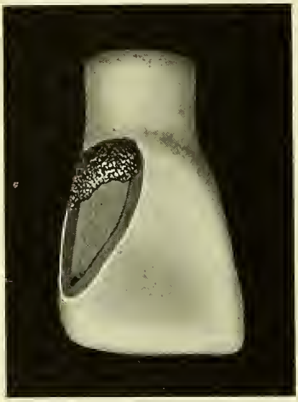


FIG. 593.—Gingival wall and margin covered, gingival portion built out to contour.

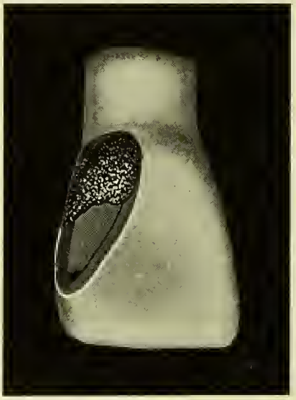


FIG. 594.—Contouring and building labial portion.

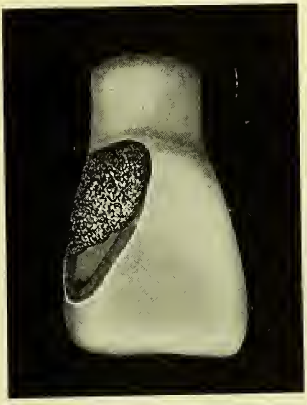


Fig. 595.—Case ready for filling incisal angle and uniting with main body of gold.

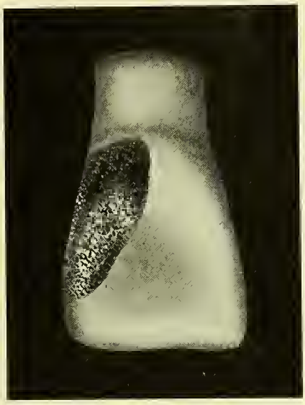


Fig. 596.—Incisal angle filled, lingual portion complete and filling ready for polishing.

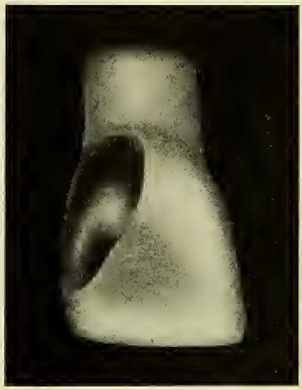


Fig. 597.—Finished filling.

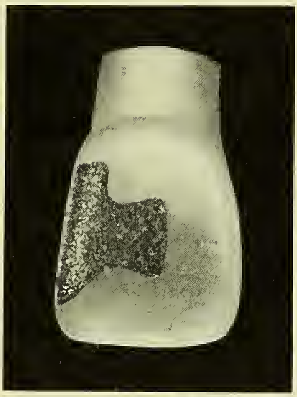


Fig. 598.—Class III filling with lingual dovetail step. It is seldom necessary to use this form.

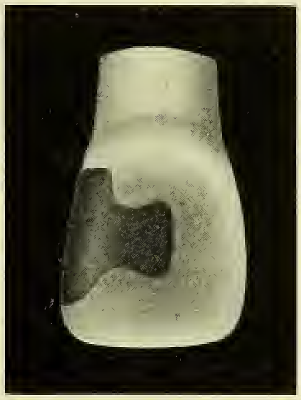


Fig. 599.—Class III filling with lingual extension completed and polished.

Class IV

These cavities will present with an incisal or lingual step.

Incisal Step Cavities.—The building of the triangular bar and the covering of the gingival margin is accomplished in the same manner as described for Class III cavities. During the preparation of the cavity the gingival wall should be given as large an area as possible, and especially secure anchorage should be obtained in well accentuated gingival point angles. Following the covering of the gingival wall and margin, the gold should be levelled up, the lamination of the gold be placed parallel to the gingival wall, and the plugging be done in the direction of the long axis of the tooth, until three-fourths of the filling has been built. Fig. 600. The angle of force should be inclined 6 centigrades toward the axial wall and never away from it. In this way is the gold closely adapted against the axial wall and lateral leverage and probable dislodgement of the filling prevented. Fig. 601. As the incisal angle is approached, the gold should be especially well annealed and the central part of the filling should begin to be raised in the form of a ridge running mesio-distally. This ridge should be elevated more and more by adding more gold on its center and then running the layers

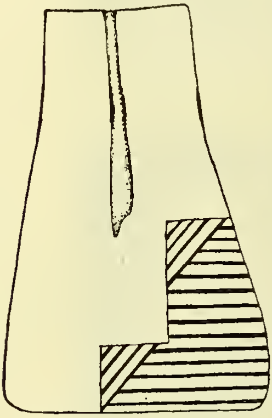


Fig. 600.—Labio-lingual view showing lamination of gold in a Class IV filling.

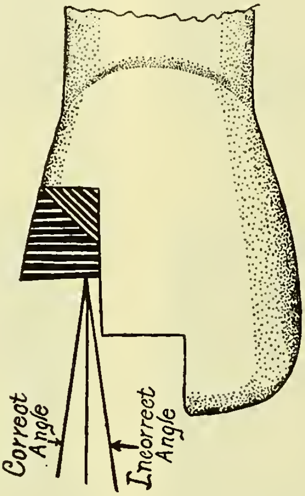


Fig. 601.—Correct and incorrect angles of force in building the main body of gold in Class IV fillings.

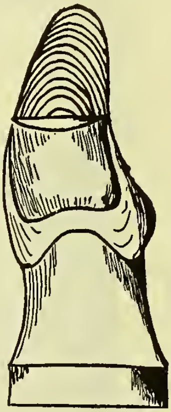


Fig. 602.—Mesio-distal view showing lamination of gold in building the angle in a Class IV cavity.

over on to its labial and lingual sides. In this way the laminae of gold, instead of running horizontally, as in the earlier building, run in convex lines labio-lingually until the angle is approached. Fig. 602.

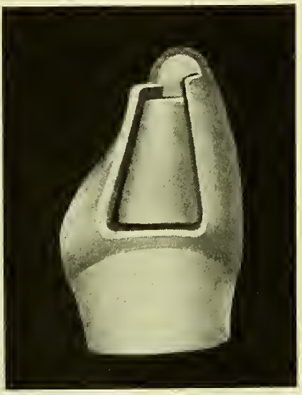


FIG. 603.—Class IV cavity prepared for filling with gold.

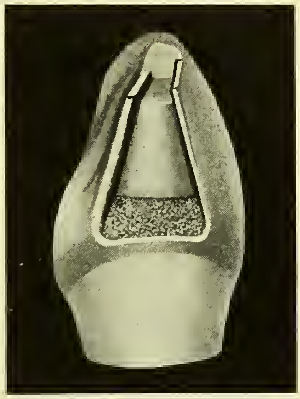


FIG. 604.—The gingival and part of the axial wall covered.

Now the gold is anchored at the extremity of the incisal step, built across the step and united to the main body of gold, when the filling is securely wedged in place. Then the lamination of gold for building the angle is continued, as described. Special condensation is accomplished as each layer is superimposed, to produce the necessary density to withstand stress. The angle should now be fully restored, the entire incisal step completely filled and all margins covered. Figs. 603 to 608.

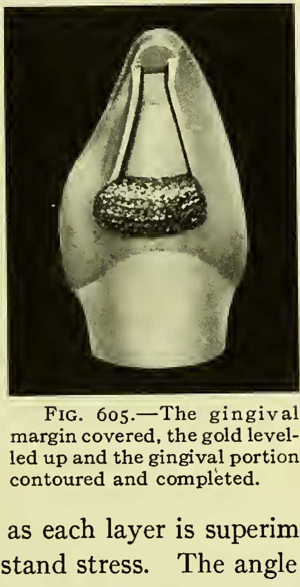


FIG. 605.—The gingival margin covered, the gold levelled up and the gingival portion contoured and completed.

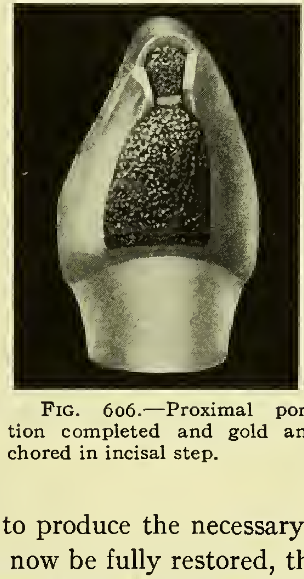


FIG. 606.—Proximal portion completed and gold anchored in incisal step.

Cavities with Lingual Step.—In filling these, the same procedures are followed as described for incisal step cavities, until the lingual step is reached, when this is filled, thus securely anchoring the filling into position. Then the lamination of gold is continued as for incisal step cavities and the angle restored.

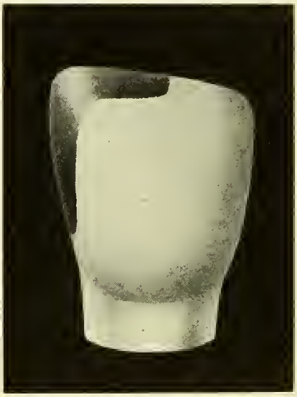


Fig. 607.—Labial view of finished filling.

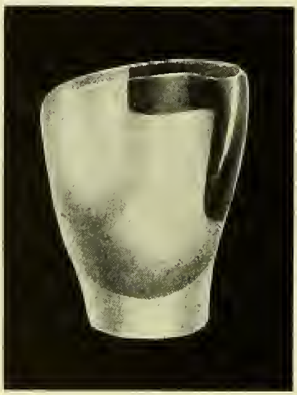


Fig. 608.—Lingual view showing restoration of lingual marginal ridge.

NON-COHESIVE GOLD AND TIN

Before the introduction of cohesive gold, non-cohesive gold and tin were extensively used for filling teeth. Even after its introduction, these materials continued to be used and the older operators were very proficient in their manipulation. However, there has been a gradual decline in their use, until tin is now almost obsolete and non-cohesive gold is used by only a few operators and in special localities. Cohesive and non-cohesive gold are still used in combination by some dentists, so as to reduce the time involved in the operation, and on account of the ease and ready adaptation of the latter material to gingival walls of class II cavities.

CHARACTERISTICS OF NON-COHESIVE GOLD

The advantages and disadvantages of non-cohesive gold may be mentioned as follows:

Advantages:

1. Insolubility in the oral fluids.
2. Ease of adaptability to cavity walls.

3. Ease and rapidity of introduction.
4. Capability of polish.

Disadvantages:

1. Inharmonious color.
2. Non-weldability and consequent lack of crushing resistance, with the result that it is not indicated on surfaces exposed to excessive mastication, and cannot be contoured.

The cavity preparation for non-cohesive gold and tin is practically the same as for cohesive gold, except that deepening of the convenience angles is omitted and, owing to lack of edge strength in the material, enamel bevels should be modified as far as possible. Simple cavities with four strong walls are advisable for their use. Non-cohesive gold may be placed on gingival walls of Class II cavities and against lateral walls of Class I cavities, the remainder of the filling being finished with cohesive gold.

All filling materials are placed more or less after a process of wedging, but the wedging principle is carried to its fullest extent with non-cohesive gold and tin. Owing to the fact that neither of these possesses the property of cohesion, as the other filling materials do, they are mechanically wedged into the cavity with great force, so that each lamina or layer is dependent on the other to retain it in place. The packing is done with hand pressure, by means of large serrated, wedge-shaped and foot pluggers, the final condensation being accomplished by means of mallet force. Illustrations of pluggers for non-cohesive gold are seen in the Woodbury set (Fig. 520). Owing to the strength of the thrust required for working tin and gold by the non-cohesive method, larger handles than those usually employed are necessary. These materials are usually manipulated in the form of cylinders of various sizes.

The Cylinder Method for Class I Cavities.—The cylinders are prepared in the manner previously described for cohesive gold. Various sizes and lengths are required, depending on the size and depth of the cavity. The cylinder should be of such length that one end will protrude 1 to 1½ millimeters above the orifice of the cavity, while the other rests on the floor or seat. The method may be used in filling small pit and fissure cavities not subjected to crushing stress and in prophylactic odontotomy operations. Fig. 609.

First, place enough cylinders against the wall farthest away from the operator to cover the wall and bring the gold near the center of the cavity. Condense thoroughly against the wall with foot or wedge shape pluggers. In large cavities, place another layer of cylinders against the first layer, and condense in the same direction, holding in position with a plugger in the left hand. Now repeat the procedure on the opposite wall, and then on the two intervening walls, leaving the center of the cavity unfilled. Fig. 610.

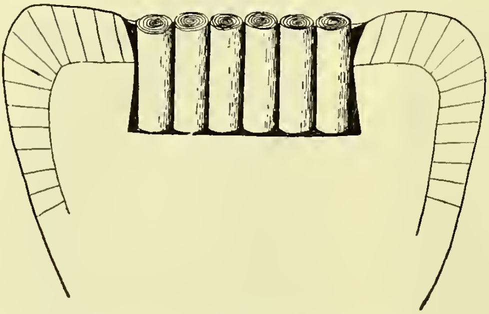


Fig. 609.—Internal view of cavity showing relation of cylinders to cavity walls.

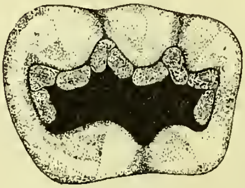


Fig. 610.—Filling an occlusal cavity with non-cohesive gold cylinders.

Next place one or more cylinders into the central opening, the number depending on the size, forcing them in until the cavity is full. Then, force an opening, by means of the wedge-shaped pluggers, into another part of the filling, and pack in one or more smaller cylinders here, repeating this process at other points until it is impossible, by great force to insert any more cylinders.

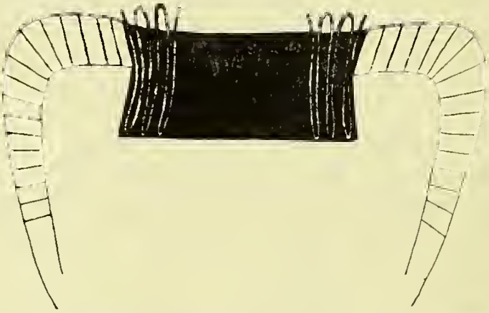


Fig. 611.—The ribbon method of filling with non-cohesive gold.

Now, thoroughly condense with foot pluggers by means of mallet force, and then burnish, after which trim to shape, grind to shape, or file to shape, and burnish again, continuing until the filling is of proper form. Then it is given a high polish.

The Ribbon Method.—This method is practically the same as the preceding, except that instead of the use of cylinders, long ribbons, rolls or ropes are folded upon themselves, starting on the floor of the cavity, against the lateral wall farthest away, and gradually condensing ribbons against all four walls, then in the center, and finally in any place they can be wedged, always carrying the ribbon to the floor of the cavity, if possible, and extending it well above the margins, to allow enough excess for finishing. At present the method is very little used.

Fillings made of non-cohesive gold have much less density, and consequently less crushing resistance than those built with cohesive gold. Dr. Black's laboratory experiments showed a much lower density for non-cohesive than for cohesive gold fillings. Fig. 611.

NON-COHESIVE AND COHESIVE GOLD IN COMBINATION

Class I Cavities.—1. Instead of placing non-cohesive cylinders in the center of the cavity as described, the central opening, left after placing the non-cohesive cylinders against the lateral walls, may be filled with cohesive gold, after which the entire surface of the filling is condensed as though it were all non-cohesive gold.

2. Or instead of this procedure, the non-cohesive cylinders may be made shorter, so as not to extend out of the cavity. After condensing these cylinders against the lateral walls, cohesive gold is anchored and built into the central opening and then out over the non-cohesive gold, thus surfacing the entire filling with cohesive gold.

3. Another method is to place several cylinders of non-cohesive gold on end and extending out of the orifice in the distal part of the cavity. Having condensed these cylinders against the distal wall, cohesive gold is started in the floor of the cavity and gradually built up against the cylinders, forward across the floor of the cavity, against the lateral walls and finally wedged against the mesial wall, thus securely anchoring it in position. The cohesive gold is now built up over the cavity margins. The final condensation should include the surface of the cohesive gold and the ends of the cylinders, which should be perfectly adapted to the margins. The filling is built to proper form and finally polished.

Class V Cavities.—The same technic may be followed in filling Class V cavities. The last method described is most often used, covering the gingival wall with cylinders or pellets of non-cohesive gold and building the remainder of the filling with cohesive gold.

Class II Cavities.—Usually the most vulnerable parts of cohesive gold fillings placed in proximo-occlusal cavities are the gingival margin and the gingivo-buccal and gingivo-lingual cavo-surface angles. This is largely due to the difficulty of properly condensing the cohesive gold in these areas. This difficulty may be overcome and this portion of the filling made much more easily and quickly with non-cohesive gold. The gingival wall is usually covered with three cylinders made long enough for one end to extend out of the cavity over against the proximating tooth, the other end being placed against the axial wall, while the cylinders are laying on the gingival wall. The cylinders are adapted to place by taking one in the foil carriers, slightly compressing it and firmly tucking it into the linguo-gingivo-axial point angle and laying it along the linguo-gingival line angle. A similar cylinder is placed in the opposite angle and a third is firmly wedged between the other two on the center of the gingival wall. These are now lightly condensed with a foot plugger. Figs. 612, 613 and 614.

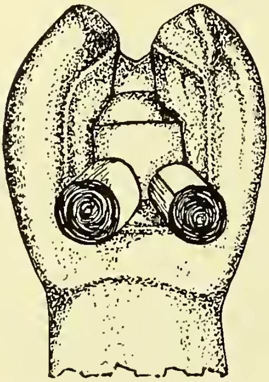


FIG. 612.—Placing non-cohesive gold cylinders on the gingival wall.*

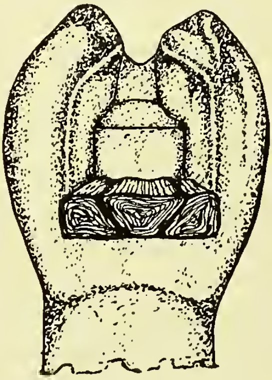


FIG. 613.—Three cylinders in position on the gingival wall.

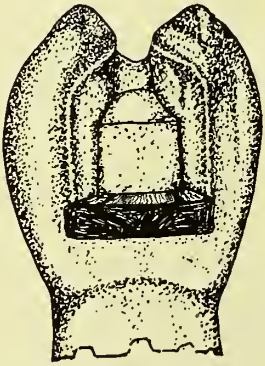


FIG. 614.—Non-cohesive gold cylinders condensed.

Cohesive gold is now started in the gingival point angles and built across the gingivo-axial line angle in a similar manner as that described for all cohesive gold fillings. Care should be observed to force some of the non-cohesive gold ahead of the cohesive gold into the angles, else the non-cohesive cylinders will be dislodged and forced out of the cavity. Cohesive gold is now built out and condensed in the form of a gradual slope over the entire length of the cylinders, after which it is levelled up and the filling of the gingival part of the cavity is complete. The cylinder ends are still protruding out of the cavity over against the proximating tooth. They should be left in this condition until the rest of the filling is completed with cohesive gold. This is now done in the manner previously described for building Class II cavities. The ends of the non-cohesive cylinders are then condensed into the cavity and over the gingival cavo-surface angle with a Black foot plugger of the regular set, foot plugger number 17 of the Woodbury set, or the quadrangle instruments of the Black or Woodbury sets.

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* Drawings by Dr. H. Schneider.

TIN

Tin is still used by a few of the operators of the old school. Its use in modern dental practice has been quite largely abandoned. Its characteristics as a filling material may be briefly summarized as follows:

Advantages:

1. Relative non-conductivity. (Lowest of all metals.)
2. Ease of introduction. (Works rapidly when non-cohesive.)
3. Ease of adaptability to cavity walls.
4. Therapeutic action. (Supposed by some to prevent decay, which action is not now conceded.)
5. Capability of polish. (Takes a high polish, but does not retain it.)

Disadvantages:

1. Inharmonious color. (Oxidizes and darkens rapidly.)
2. Lack of crushing resistance and edge strength.
3. Flow. (Very high in this regard.)
4. Disintegrates in the fluids of the mouth.

Tin, when pure and freshly cut, is cohesive (the separate particles clinging to each other) like gold. It rapidly loses this property, however, on exposure to the atmosphere, and gradually becomes non-cohesive. Until recently it was worked almost exclusively after the non-cohesive method. There have been introduced from time to time, several preparations of tin of a very cohesive nature. A cohesive form of tinfoil also was to be obtained, known as Ambler's. These are all now obsolete.

Tin is placed on the market in sheets about four inches square, the same sizes and numbers as gold foil. It is prepared by the manufacturer in the same manner as gold, by rolling an ingot into strips and then rolling thinner for the higher numbers and beating by machinery for the lower numbers. The number indicates the number of grains to the sheet, viz., a sheet of number four foil weighs four grains; number ten, weighs ten grains, etc. Tin is worked in the same manner as non-cohesive gold.

FINISHING AND POLISHING GOLD FILLINGS

In previous chapters, the necessity for full and complete restoration of occlusal form and proximal contour has been accentuated. In the building of all fillings, material for restoration of the proper contour and contact point should be provided. The original cusps, grooves, and ridges on occlusal surfaces should be carefully restored. The building up to full form of the marginal ridges bounding the mesial and distal margins of the lingual surfaces of the anterior teeth, and of those bounding the occlusal surfaces of the bicuspids and molars is essential to ideal results. The marginal ridges are important factors in the incision and mastication of food and if they are not adequately provided for in the completed filling, the masticatory function is lowered and the partial disuse and malocclusion resulting frequently will be productive of pericemental disturbance and change of position of the tooth. Improper functioning of the organ will finally lead to pathologic conditions of the gingivae, as well. All fillings should be built slightly overful, especially in the locations mentioned, to allow for proper trimming down in the finishing and polishing process.

Class I and V Fillings.—Following is the method of finishing and polishing fillings in pit and fissure and gingival third cavities:

1. *Remove the excess* with Black's, Prime's, or Pichler's trimming knives, Black's or other files, carborundum stones, gem points or sand and emery discs, depending on the size, location and shape of the filling. Fig. 615. The general direction of the cutting should be toward the margins. Do not use rough stones as the outline of the cavo-surface angle is approached, for fear of damaging the margins; changing to knives, fine gem stones, or discs for this purpose. Fig. 616. Trim or grind the filling down until the original shape of the tooth is restored, the operation on occlusal surfaces frequently requiring the application of much esthetic taste, as well as mechanical skill, to carve grooves and ridges and cusps to their original anatomical form.

2. *Polish*, first with garnet and then with cuttle-fish discs, in locations where these will reach readily, finally going over the surface, if a specially high finish is desired, with crocus discs, or with chamois, felt or moose-hide buffers dipped in whiting, tin oxide, or rouge. In pits and fissures, where the disc is not applicable, after the final shaping of the filling, the surface may be gone over with finishing burs, hand or engine burnishers (Figs. 617 and 618), which will give a high burnish; or, if preferred, the use of wood points and wet pumice may be resorted to, finally going over the surface again with the chamois, felt or moose-hide wheels carrying whiting or rouge. Sulci discs also are valuable for this purpose. Care should be observed to avoid polishing away the fine detail previously carved on occlusal surfaces.

Method of Finishing and Polishing Proximal Fillings. 1. *The Gingival Portion.*—After thorough burnishing, the excess at the gingival portion, up to a point slightly gingival to the contact point, is first removed by the use of keen Prime, Pichler, or Black knives. This portion is then gone over with the Black or other files or the Rhein

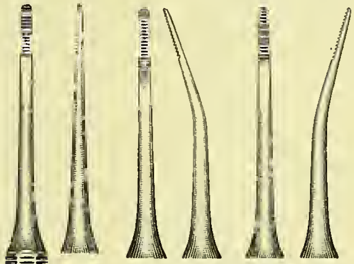


FIG. 615.—Wedelstaedt files.

FIG. 616.—Disk mandrel.

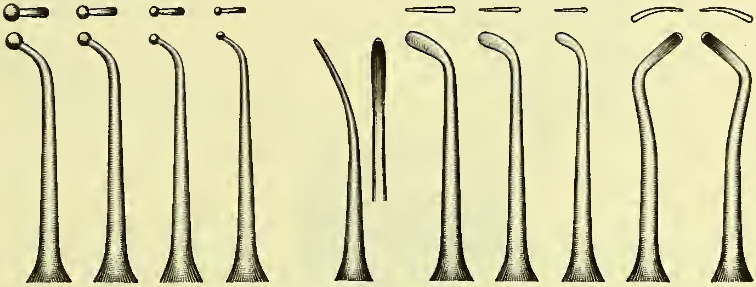


FIG. 617.—Hand burnishers.

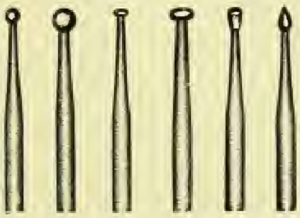


FIG. 618.—Engine burnishers.

approximal trimmers, 31 and 32, until the filling is flush with the gingival margin. Figs. 619 and 620.

2. *The buccal or labial and lingual portions* then receive attention, the excess being removed by the use of the knives, the files, or where convenient, small stones, sand and emery discs. Fig. 621.

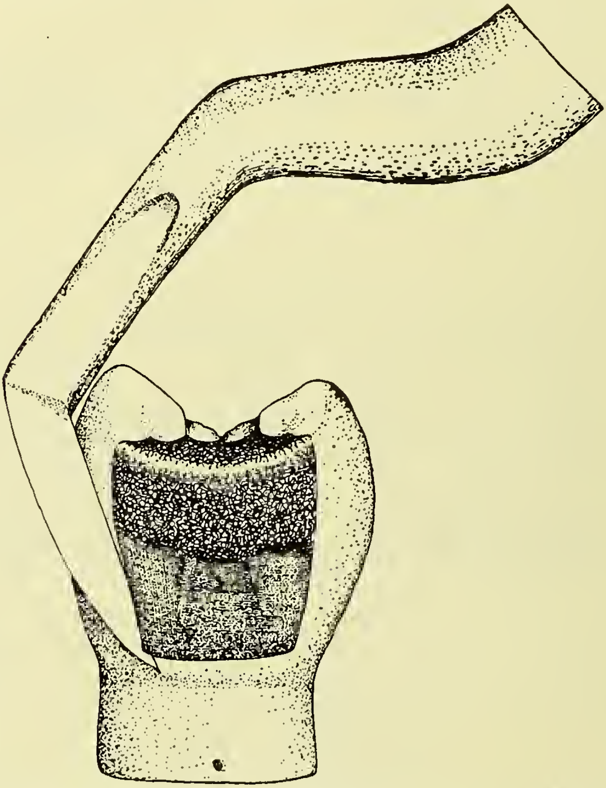


Fig. 619.—Removing the excess at the gingival portion with a Black knife.

3. *The occlusal or incisal portions* next receive attention in the same manner, leaving the contact point untouched. The technic for finishing and polishing the occlusal surfaces is the same as that described for pit and fissure cavities. Occlusal surfaces often show abrasion in adult life, the result of wear incident to mastication. In these cases the occlusal surfaces should not be built to their original anatomical form, but should correspond, when completed, to the other teeth in the mouth. Fig. 622.

4. *The entire filling* is gone over again, with the exception of the contact point, with the finer polishing strips and discs, using the discs

only on the labial, buccal, lingual, incisal or occlusal margins, utilizing the strips for the shaping of the interproximal portion. Figs. 623 and 624.

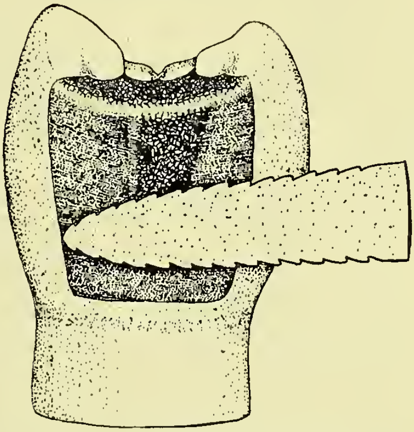


FIG. 620.—Application of the file to the gingival portion.

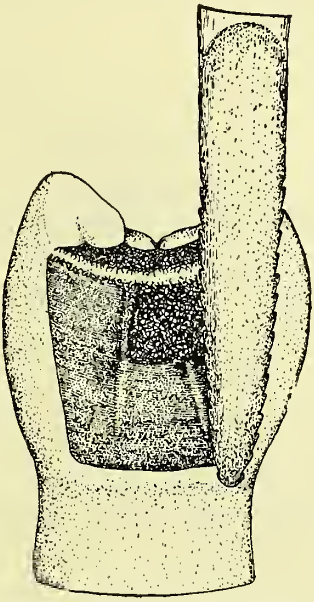


FIG. 621.—Filing the buccal and lingual portions.

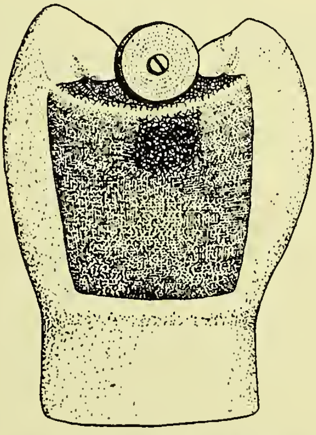


FIG. 622.—Use of a small stone on the occlusal surface.

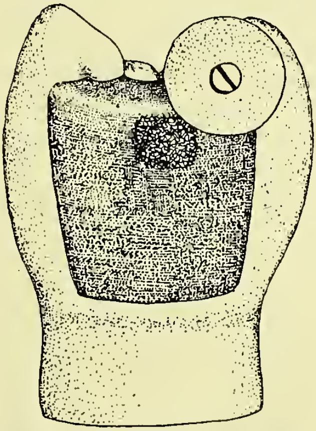


FIG. 623.—Polishing with the disk.

5. *The contact point* should now remain as a small marble or oval contact, as nature intended it, and is now gone over (being careful not to

flatten it) with a fine linen polishing strip, making increased separation, if necessary for this purpose. Fig. 625.

6. In case a still higher finish is desired, the exposed surfaces are now gone over with whiting and rouge on the buffers, wood points or fine bristle brushes.

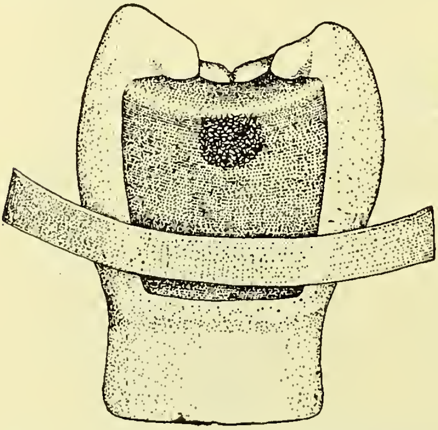


Fig. 624.—Application of the polishing strip to the interproximal portion.

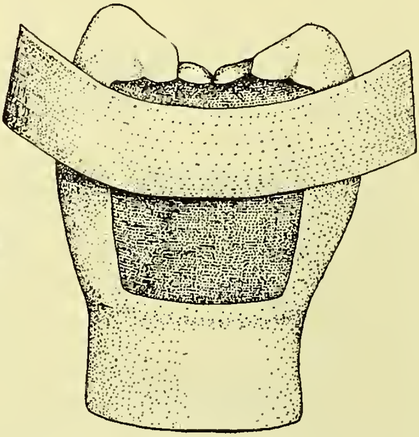


Fig. 625.—Polishing the contact point

Bibliography

Black, G. V.: "Operative Dentistry," 6th ed., vol. 2.

Woodbury, C. E.: "Making and Filling Cavities in Proximal Surfaces of Front Teeth with Gold Foil," 1929.

Bureau of Standards Research Paper, no. 32, Dec. 1928.

True, Harry A.: Control of caries in anterior teeth by filling, Jour. Amer. Dent. Assoc., May 1928, p. 831.

CHAPTER XX

THE CAST GOLD INLAY—INDICATIONS FOR USE—CAVITY PREPARATION—PATTERN WAXES—INVESTMENTS

An inlay may be defined as a material, usually gold or porcelain, which has been so constructed out of the mouth and later cemented in one piece into the prepared cavity of a tooth, that it will perform the required functions of a filling.

HISTORICAL DATA

The modern cast gold dental inlay was brought strongly to the attention of the profession by Doctor William H. Taggart, of Chicago, and introduced by him into dentistry in 1906. His method consists in the making of a wax model of the proposed restoration, investing it, burning out the wax, casting gold into the resulting mold, thus duplicating the wax pattern in gold, and then cementing the inlay into the previously prepared cavity. Before that time, other methods of constructing gold inlays were in more or less limited use in dentistry, but were largely unsuccessful, on account of the crudeness of the procedures followed and the poor results obtained.

One of these methods, which might be termed the "matrix method," introduced by Dr. Charles Alexander in 1887, may be briefly described as follows: Construct a matrix of the cavity by burnishing into it platinum or gold foil, as for porcelain inlay work. While in position in the cavity, partially fill the matrix with loosely packed crystal gold, remove and flow in a small amount of twenty-two karat solder melted over a Bunsen burner or with a blow-pipe. Replace in the mouth and reburnish, to perfect the adaptation, after which remove, invest and completely fill the matrix with the twenty-two karat solder. Polish and set the inlay with cement.

Another procedure was as follows: Pack the cavity full, but loosely, with crystalline gold, remove and invest, leaving a large opening at the top of the investment. After heating, flow in twenty to twenty-two karat solder, which fills in the meshes of the gold and makes a solid inlay. Remove the investment, set with cement and polish.

Although the profession is deeply indebted to Doctor Taggart for his work in greatly improving the methods of constructing the gold inlay, it must be said that these methods were not entirely original with him, but were a revival or adaptation of very old principles, used over long periods of time in mechanics and the arts. The "Cire Perdue" or disappearing model or "wax wasting" process of casting was in common use in the founding art thousands of years ago. This is true also of the present centrifugal and pressure methods of casting.

The historians, Herodotus and Diodorus, refer to the casting in bronze, by the disappearing wax model process, of bronze statues that were set up in the Temple of Belus in Babylon, 2230 B. C. The golden calf of Aaron, referred to in holy writ, and which was cast from the jewelry of the Hebrew worshippers, supposedly dates back to 1491 B. C. The Roman emperor, Nero, is said to have carved a bronze figure of himself to be set up before his house near the Temple of Venus in Rome. This statue was cast by the disappearing wax model process. Lycippus, the Greek sculptor, was renowned for his works in bronze. The Greeks were casting works in bronze by the Cire Perdue method as early as the eighth century B. C. Lysistratus mentioned similar methods of casting in the year 328 B. C. Numerous references of similar nature may be found in the literature of many nations, extending through the ages up to modern times, all of these demonstrating that our present methods are duplicates or modifications of very old procedures. However, Doctor Taggart, in introducing these methods into dentistry never claimed that he originated the Cire Perdue. He adapted the procedure to dental usage, devised a special casting machine, wax, investment material and other very ingenious accessories and was the first man in the world, as far as is known, to successfully cast gold to fit a tooth cavity without tooling. His original casting machine has been withdrawn, although his waxes, investments, etc. are still obtainable. Taggart's investment and wax are not on the A. D. A. specified lists for investments and inlay waxes.

As a result of his invention, the practice of dentistry was almost revolutionized, the gold filling, which had occupied first place, being temporarily almost abandoned. The profession has always been prone to worship new and strange gods, and in the early history of this new method many men, not realizing the necessity for perfecting a technic and observing the minutiae of detail required, produced very crude results, to the discredit of the method. At that time Doctor M. L. Rhein of New York spoke of the average inlay as "A floating island of gold in a sea of cement." Since then some of the more scientific minds in the profession have been laboring to improve the methods of construction, through a study of the properties of waxes, investments, gold, etc., in an endeavor to take the gold inlay out of the realm of empiricism and place its use on a more scientific foundation. As a result of their labors and the work of the U. S. Bureau of Standards many improvements have been made and much additional knowledge has been gained as to methods of manipulation and the conditions indicating its use. Now it is realized that the gold filling and the gold inlay have definite functions to perform and that they will so do if properly constructed and used under the conditions which indicate them. However, it is still found that the power of the gold inlay to control caries is less than that of a well constructed gold filling, but that it is indicated in inaccessible localities and as abutments for bridgework. Fig. 626.

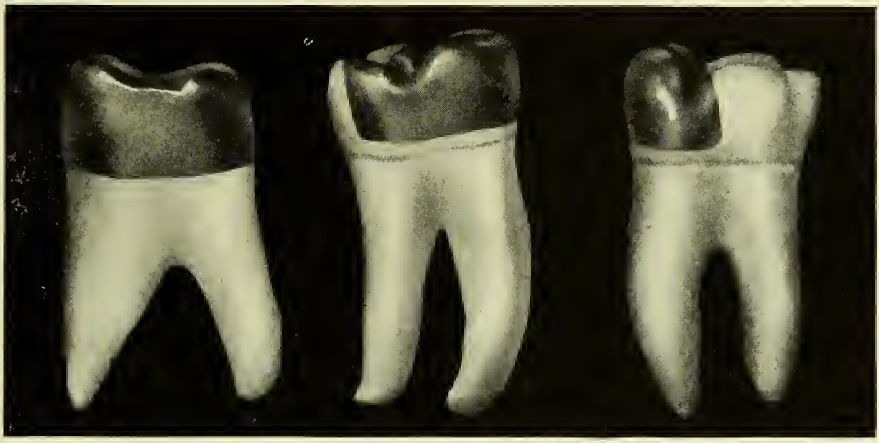


FIG. 626.—Extensive gold inlay restorations.

ADVANTAGES AND DISADVANTAGES

The advantages and disadvantages of the gold inlay may be mentioned as follows.

Advantages

1. Indestructibility of the gold in the fluids of the mouth.
2. Adequate crushing resistance.
3. Freedom from volume change after placement.
4. Convenience of manipulation.
5. Capability of polish and restoration of anatomical form.

Disadvantages

1. Lack of adaptability to cavity walls.
2. Necessity of exposing the cavity to the saliva after completion of the cavity preparation.
3. Inharmonious color.
4. High conductivity of thermal changes.
5. Necessity for a cementing medium.

The gold used in the construction of the inlay possesses the same degree of indestructibility in the oral fluids as that used for the gold filling, since it is not acted upon or oxidized by any of the substances with which it comes in contact in the environment in which it is placed. However, the material used for cementing it into the cavity, usually oxyphosphate of zinc cement, is soluble in this media and, consequently, has a tendency to in time disintegrate and admit moisture, germs and fermentative material. Formerly, pure gold was much used for casting inlays. This was found to possess, in many cases, insufficient crushing resistance, so that alloys of gold with copper, silver, platinum and other substances are now largely used in varying proportions, depending on the size of the inlay, the stress to be resisted and the purpose which it is intended to serve. With these, adequate resistance to crushing, tensile and all other forms of stress is provided. These alloys are also practically free from expansion, contraction and flow after placement, although they possess the property of contraction during cooling after casting. The construction of an inlay requires much more time than does a gold filling. It also requires a high degree of skill. However, much of the work may be done in the laboratory during the absence of the patient, so that the time of the patient is conserved. Also, if the dentist has a laboratory assistant, his own time is conserved. If not, he may perform the laboratory procedures outside of the time devoted to the reception of patients. In this way, the use of the inlay may be looked upon as a time saver, since a large number of restorations may be performed within a given time at the chair. The inlay also relieves both dentist and patient of the strain incident to prolonged gold building operations in large and inaccessible locations. In this respect it may be looked upon as a convenience, although a high degree of skill, thorough knowledge of the physical and chemical properties of the materials used and strict attention to detail is essential to produce desirable results. The gold inlay is capable of the same high polish as is the gold filling. Restoration of anatomical form is more easily accomplished with the inlay, since this may be readily done in the soft wax of the pattern.

Also, if it is found that the contact point has not been properly restored on the casting, it may easily be soldered on before insertion into the cavity. The gold inlay is not adaptable to cavity walls in a manner to hermetically seal the cavity. Therefore, it must be placed with cement. This is one of the weak points in inlay construction, since the cement is soluble in the fluids of the mouth. The cement line is, with properly fitting inlays, very thin, but all of the burnishing possible will not entirely eliminate it at the margins. Even if it did, there still would be less perfect adaptation to cavity margins than that obtainable with the hammered gold filling. The larger the inlay, the greater will be the length of the cement line along the cavo-surface angle and the greater the tendency to disintegrate in this area. Owing to lack of perfect adaptation to cavity walls, the inlay cannot be gripped into place by the elastic dentinal walls of the cavity. The possibility of wedging cohesive gold into place between opposing walls has previously been stressed in discussing the advantages of this latter material. This shortcoming of the gold inlay must always exist as a prominent disadvantage in its use, and must be recognized by increasing the retention form of the cavity, so that the gold may be keyed into position as securely as possible. No dependence can be placed on the adhesive properties of the cement for this purpose and this material can be used only as a sealing agent between the inlay and the cavity walls. Another disadvantage of the inlay is the necessity of exposing the walls and margins of the cavity to the oral fluids during construction of the wax pattern. Previously, attention has been called to the desirability of exclusion of saliva from the field of operation during cavity preparation and manipulation of filling materials and of adapting these materials against sterile, freshly cut walls, from which all foreign matter has been excluded. The color of the gold inlay is objectionable in like manner and in the same degree as the gold filling. The conductivity is also similar to that of the gold or amalgam filling, although this may be reduced slightly by the interposition of the cementing medium.

INDICATIONS AND CONTRA-INDICATIONS FOR USE

The **indications** for the gold inlay may be mentioned as follows, viz.:

1. For restoration of large abraded surfaces, where application and retention of gold foil would be difficult.

2. As a substitute for the shell crown in badly broken-down posterior teeth.

3. As a time saver to operator and patient.

4. In cavities with sub-gingival margins and where prolonged exclusion of moisture is impossible.
5. In teeth relatively immune to caries.
6. In large proximo-occlusal or M. O. D. cavities, difficult of access.
7. In invalid, young, or old patients, unable to bear prolonged operations.
8. In teeth with weakened peridental membranes.
9. As abutments for bridge work.

Often on large abraded surfaces, a cavity cannot be prepared and it then becomes necessary to depend on the use of pins inserted into the dentin for retention. In these cases, the inlay becomes an "onlay" or "pinlay," the pins being the only means of retention. Also it is often difficult to apply proper angles of force and the necessary malleting to secure proper condensation of cohesive gold. In addition, in cases of this nature it frequently becomes necessary to open the bite and restore many abraded surfaces. For these reasons, the gold inlay will often be selected in these cases. The substitution of the gold inlay for a gold crown eliminates the band with its ever present tendency to produce gingival disturbance. In cases where the time at the chair of the patient or operator is paramount the gold inlay is advantageous, but the other factors should be considered in choosing it, remembering that the total time consumed is usually greater for the inlay. In some patients, and with some large cavities, it is occasionally difficult or impossible to exclude moisture for any great length of time for the introduction of gold or even amalgam. In these cases, the inlay is valuable. In teeth relatively immune to decay, there will be less tendency to disintegration of the cement line and recurrence of caries. The tendency to immunity usually increases with age. Bearing these factors in mind the general indications for the gold inlay will be less pronounced in young patients and patients exhibiting great caries susceptibility than in older patients with relative immunity. In large Class II cavities in molars, difficult of access, the inlay or amalgam are now considered the materials of choice and often a decision must be made between them. This is particularly true of disto-occlusal and M. O. D. cavities where the gold building operation is very difficult and tedious. Invalid, young, or aged patients often should not be subjected to tedious operations. Also these types often contra-indicate the use of the rubber dam and favor inlay restorations.

Young teeth with undeveloped roots and teeth with weakened peridental membranes from pericementoclasia, will not bear the malleting required for introduction of gold foil and often point strongly to the gold inlay restoration. Gold inlays are quite largely used as abutments for bridges and serve a useful purpose in this capacity, but it must be remembered that they possess the shortcomings mentioned under the head of disadvantages, for whatever purpose they may be used.

Contra-indications.—Gold inlays are, as a rule contra-indicated in small cavities, shallow cavities, and proximal cavities on anterior teeth not involving the angle, unless these latter are large and the lingual wall is lost, thus allowing ready withdrawal of the wax model and insertion of the inlay from the lingual aspect. Even here a gold filling will be better. Following the introduction of the gold inlay and the silicate filling, the use of cohesive gold as a filling material rapidly diminished. Now it is surely returning to the place it justly deserves, since the silicate filling has proven a failure as a tooth preservative and the gold inlay has fallen far short of the expectations of many who so loudly proclaimed its virtues. However, there are still many conditions which justify the use of both and the gold-building operation far exceeds all others in the college clinic for developing technical skill and manipulative ability.

PREPARATION OF CAVITIES FOR GOLD INLAYS

The fundamental principles as previously outlined, are applicable to the preparation of cavities for all types of restoration. It is only necessary to make certain slight modifications of cavity form, depending on the physico-metallurgical characteristics and the working properties of the various materials. All cavity preparations, for whatever materials, should be made with the saliva excluded, to perfect the view of the cavity, to diminish sensitivity and to maintain asepsis. *Access* for inlay work should be obtained through separation of the teeth and not through extensive cutting of tooth structure. The extension of cavity walls and margins merely to enable the operator to insert an inlay in preference to some other material is reprehensible and against the best interests of the patient being served. In large cavities, it will occasionally be necessary to obtain previous separation with gutta-percha. Here the rapid separator may be dispensed with and the gutta-percha be used to force away overhanging gingival tissues from gingival margins as well as for separation. No special *convenience form* is necessary and the deepening of point angles is not permissible.

Resistance form is provided by flat seats placed at right angles to the line of stress as in other filling materials. All line and point angles should be sharp and clearly defined. Parallel or slightly diverging cavity walls, to permit ready withdrawal of the wax pattern, are necessary. This divergence should not be too much accentuated, else the resistance and retention form will be diminished and the inlay be more likely to be unseated. Too marked divergence of walls also involves unnecessary waste of tooth structure and enlarges the total length of the marginal outline, thus exposing it to a greater tendency to cement disintegration and recurrence of decay; or, if the divergence is made at the expense of the seat, resistance form is diminished by lessening the area of the seat.

Retention form will have to be accomplished (1) by limiting the divergence of lateral walls as much as conditions will admit; (2) by so dovetailing the step form of the cavity in Class II and IV cavities that the inlay will be locked into place against lateral stresses; (3) by the occasional use of 20 gauge pins of iridio-platinum or special gold alloy made for this purpose, attached to the inlay and cemented into the dentin; (4) by the use of 16 to 14 gauge pins in the pulp chamber and canals of non-vital teeth; and (5) by the use of cement. Very little dependence can be put on cement for this purpose, consequently, it should usually be considered merely as a sealing agent between the inlay and the cavity walls and margins, to fill in the joint due to lack of adaptation and grip of the cavity on the inlay. Owing to the necessity for withdrawal of the wax pattern without distortion, deepening of point angles or the use of undercuts or dovetails on lateral walls is prohibited. On completion of the cavity preparation, the operator should be enabled to see every part of every wall in the mouth mirror when it is placed at right angles to the seat (Fig. 627); otherwise there will be wall inclinations or undercuts which must be removed. The straightening up of undercut walls must be accomplished by further cutting or by filling in with cement. In doubtful cases, it will be well on completion of the cavity to take an impression of it in modelling compound to see that it draws without distortion. *The enamel wall* is prepared in the same manner as described for cohesive gold fillings. Long, obtuse bevels should be avoided, thus preventing the formation of feather edges on the inlay. The bevel should extend the entire thickness of the enamel. Figs. 628 and 629. Margins over which the wax pattern has to travel during withdrawal should be highly polished to avoid roughness and marring of the wax. *The toilet of the cavity* should be carefully performed. It should be thoroughly dried and sterilized. Before setting the inlay, the cavity should be given a bath,

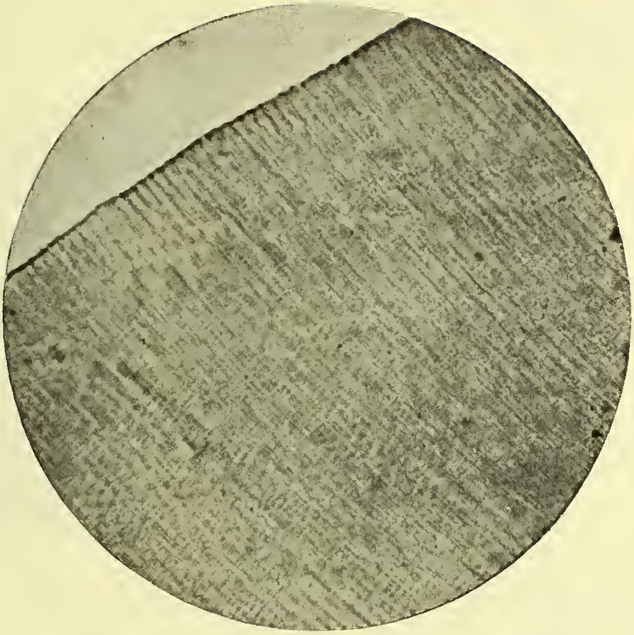


FIG. 628.—Enamel prisms in longitudinal section. Nasmyth's membrane on the surface. (Courtesy of Dr. John B. Stein.)

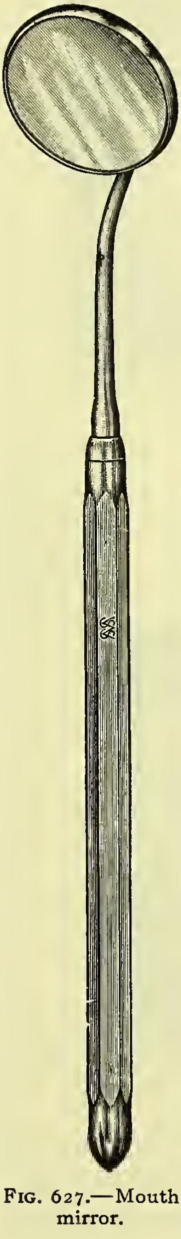


FIG. 627.—Mouth mirror.

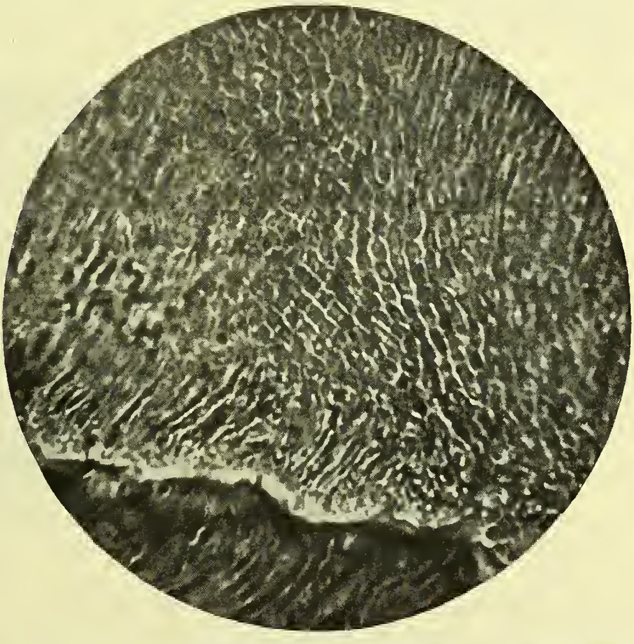


FIG. 629.—Dento-enamel junction. Enamel spindles are seen in the deep layers of enamel next to the dentin. The enamel rods are shown in longitudinal, transverse and oblique sections. (Courtesy of Dr. John B. Stein.)

first of chloroform and then in alcohol to remove traces of wax, fatty, oily and mucinous matters, or any other substances which may have been in contact with it.

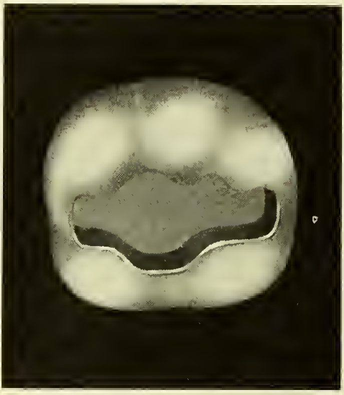


FIG. 630.—Cavity preparation in a lower first molar for a gold inlay.

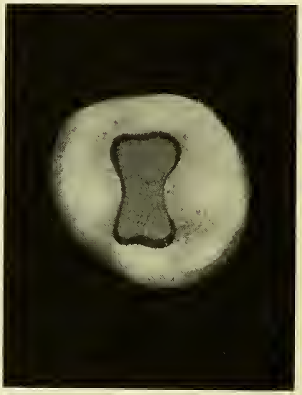


FIG. 631.—Cavity for gold inlay in a bicuspid.

Class I and Class V Cavities.—The method of preparation described for gold foil will usually suffice for these two classes of cavities. In general, they may be made slightly deeper than for foil, to provide for better retention. Parallel walls will usually be sufficient to admit withdrawal of the wax and seating of the inlay. Convenience points or undercut walls are contra-indicated. Gold foil is preferred for small

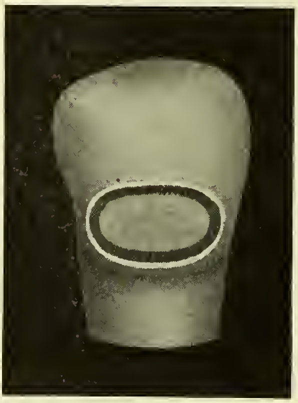


FIG. 632.—Class V preparation on a lower bicuspid for a gold inlay.

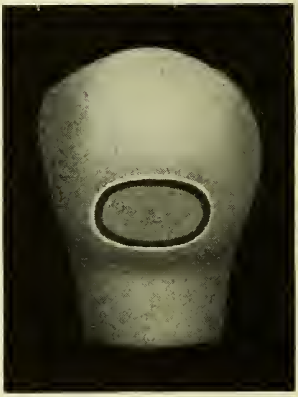


FIG. 633.—Gold inlay preparation on a lower bicuspid.

and medium sized cavities of this class, when not exposed to view. For larger sized cavities, where esthetics are not important the gold inlay may be selected, if the other factors mentioned are favorable. Figs. 630 to 634.

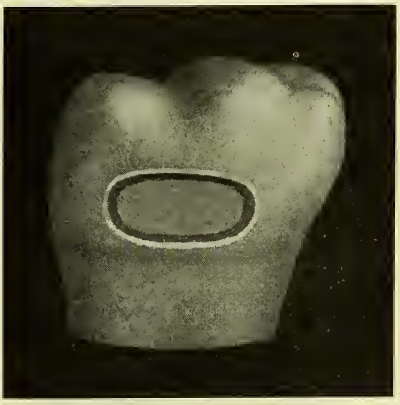


FIG. 634.—Gold inlay preparation on a lower first molar.

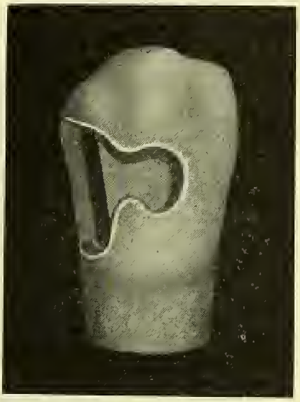


FIG. 635.—Class III preparation for gold inlay on lingual surface of a cuspid.

Class III Cavities.—Gold inlays are usually contra-indicated here. Gold fillings or porcelain inlays are in many instances preferable. The silicate filling is a temporary expedient. If the gold inlay is used at all, the cavity must be so prepared as to admit of withdrawal of the wax pattern and insertion of the inlay from the lingual aspect. Adequate separation of the teeth is essential. A seat must be provided

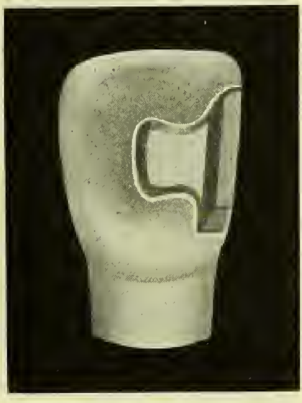


FIG. 636.—Class III cavity preparation for gold inlay on an incisor.

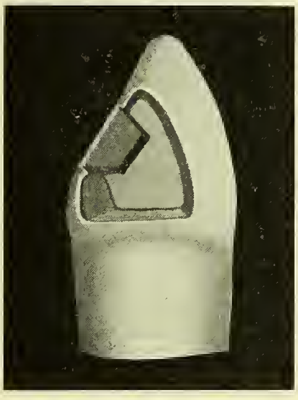


FIG. 637.—Class III cavity preparation for a gold inlay on a cuspid.

on the labial wall, and the gingival and incisal walls should slightly diverge, to permit proper withdrawal of the wax and seating of the inlay from the lingual direction. All line and point angles should be distinct and definitely formed and no bevel is permissible on the labial enamel walls. Often the use of a dovetail extension cut into the lingual surface of the tooth will be advisable to provide better resistance and retention form. This dovetail must show proper "draw," with no undercutting. Its use will also afford better access to the main cavity. Figs. 635 to 640.

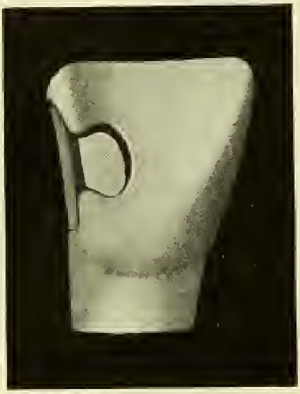


Fig. 638.—Class III preparation on a central incisor.

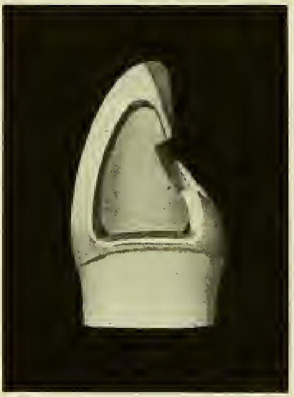


Fig. 639.—Class III preparation on a lateral incisor.

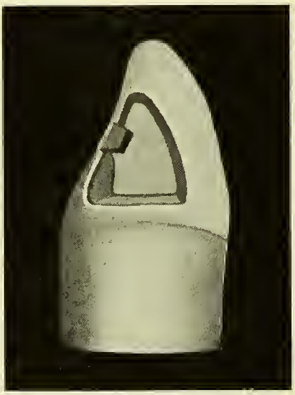


Fig. 640.—Class III preparation on a cuspid.

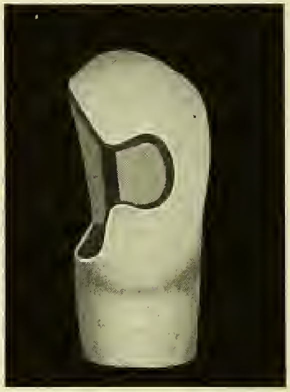


Fig. 641.—Class IV cavity preparation on a cuspid for a gold inlay.

Class IV Cavities.—Frequently it is difficult to determine what material to use in Class IV cavities. Esthetics and utility must be considered. Where both angles are destroyed or in cases of extensive involvement, the porcelain jacket crown excellently fills both requirements. If the cavity is a mesio- or disto-incisal, the porcelain inlay will meet the esthetic demands, but from the standpoint of utility, failure often occurs from fracture of the incisal portion under heavy stresses. In some instances, where gold will not be too conspicuous, a choice must be made between a cohesive gold filling and a gold inlay. Better anchorage and more lasting results may be obtained with a properly and carefully built gold filling. However, the gold inlay has shown its usefulness in a fair percentage of cases. For the gold inlay an incisal or lingual step form may be used. Fig. 641.

Incisal Step Form.—As broad a seat as possible should be prepared on the gingival and pulpal walls. The labial enamel should be preserved as much as conditions will admit, the lingual wall of the proximal and step portions being cut well back. The labial margin should follow a straight line from the labio-gingival cavo-surface angle to the incisal surface, while the lingual margin, beginning at the linguo-gingival angle should parallel the labial margin until, owing to the wedge or conical shape of the tooth, it is lost on the lingual surface near the middle third of the tooth. The balance of the lingual margin is then cut over on to the lingual surface until it becomes the lingual boundary of the axial wall, follows it to the top of the step, when it forms the lingual boundary of the step. The axial and all other walls should be made flat, line angles should be definite and care be observed to see that proper "draw" is given the cavity in the linguo-incisal direction. For additional retention, a pit may be cut into the dentin at the extremity of the pulpal wall of the step for the reception of an 18 gauge platinoiridium pin, which is withdrawn in the wax pattern and attached to the inlay in casting.

Lingual Step Form.—This preparation often results in less display of gold and for that reason it is preferred in many cases. A step is cut over on to the lingual surface in a manner similar to that described for cohesive gold. The proximal and lingual portions should be prepared to admit of withdrawal of the wax from the lingual aspect. A flat labial wall against which the inlay is seated should be preserved if possible. The lingual step must not be cut so deep as to endanger the pulp. It should show sharp line angles, but must allow ready withdrawal of the pattern. It must be strongly dovetailed gingivo-incisally at its extremity so as to lock the finished inlay into place. It should occupy the middle third of the lingual surface and not approach the incisal surface too closely. It will be necessary to prepare the labial cavo-surface angle in both step forms for Class IV cavities to allow for proper withdrawal of the wax model, consequently, it cannot be made to follow the exact inclination of the enamel rods in that locality.

Class II Cavities.—Class II cavities should be prepared in a manner quite similar to that described for the gold filling. Figs. 642 to 648.

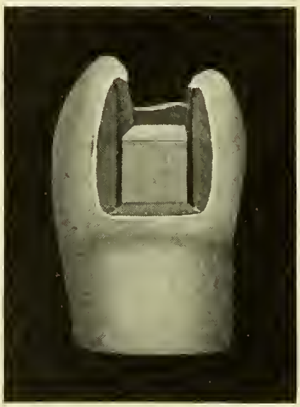


Fig. 642.—Class II cavity preparation on a bicuspid for a gold inlay.

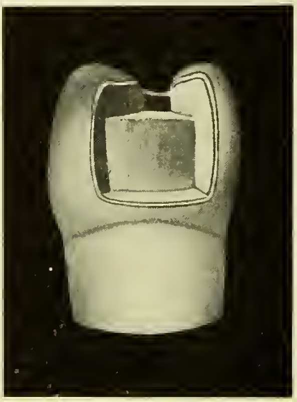


Fig. 643.—Class II cavity on a bicuspid for a gold inlay.

All line angles must be sharply defined and all walls made flat and shaped to allow for proper seating of the inlay. The buccal and lingual walls in proximity to the axial wall, instead of being made to converge as for the gold filling, must be cut parallel in the mesio-distal plane and parallel or very slightly diverging in the axial plane. The remaining part of these walls is then flared out to the buccal and lingual margins. There must be no overhang to the axial wall to interfere with withdrawal

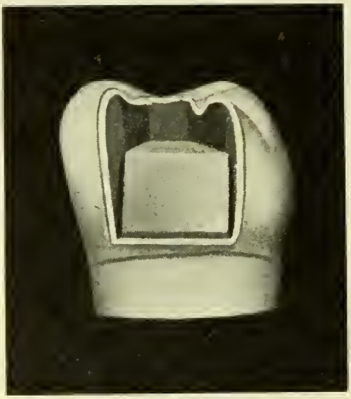


Fig. 644.—Gold inlay preparation on a molar.

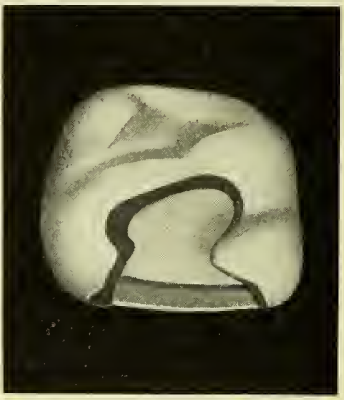


Fig. 645.—Class II preparation on an upper molar.

of the pattern. The gingival and pulpal walls must be broad and flat to afford adequate stability. The step must be dovetailed bucco-lingually at its extremity to lock the inlay securely in place and must be deep enough to afford sufficient bulk of gold for strength. The bucco- and linguo-gingival cavo-surface angles must be extended well into relatively immune areas. Following are the approximate measurements for ordinary proximo-occlusal cavities prepared for gold inlays in molars. Fig. 649. These measurements will vary slightly, depending on the size of the tooth and the amount of caries involvement. In large cavities involving removal of cusps, these measurements are not applicable.

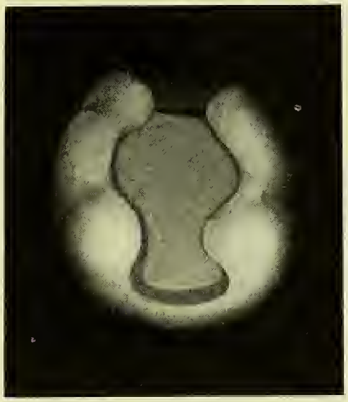


Fig. 646.—Gold inlay preparation on a lower first molar.

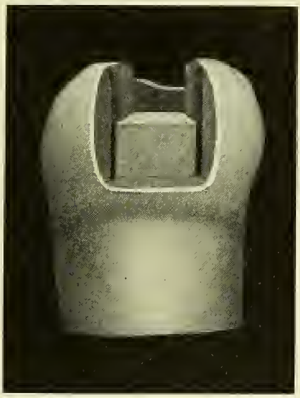


Fig. 647.—Gold inlay preparation on a molar.

Approximate Measurements for Class II Cavities in Molars

Width of gingival wall mesio-distally	1.5 millimeters
Length of bucco- and lingo-gingival line angles	2.0 millimeters
Length of gingivo-axial line angle	2.5–3 millimeters
Length of axio-pupal line angle	2.5–3 millimeters
Width of axial wall bucco-lingually	2.5–3 millimeters
Width of proximal portion from buccal to lingual cavo-surface angle	5–6 millimeters
Depth of pulpal wall	1.5–2 millimeters
Width between buccal and lingual walls at junction of proximal with occlusal portions	1.5 millimeters
Mesio-distal width of proximal portion next to axial wall	0.5–0.75 millimeters

In mesio-occluso-distal cavities, the axial walls should slightly converge from the gingival to the pulpal wall to allow for easy seating of the inlay. Figs. 650 to 653. In cases where the cusps are weakened, it will often be advisable to cut them away and restore the occlusal portion with the gold of the inlay, else they may be later fractured or split away during mastication. Figs. 654 to 657. In badly broken down molars, weakened walls or cusps should be similarly removed. In cases of this nature, the gold inlay is often the ideal form of restoration. Figs. 658 to 663. In pulpless teeth, firm anchorage may be secured by

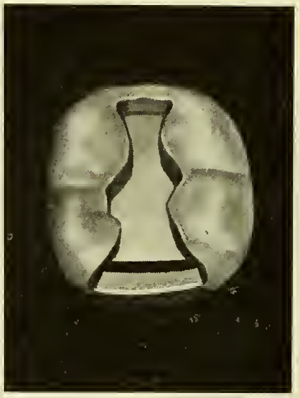


FIG. 648.—Cavity preparation on a molar for a gold inlay.

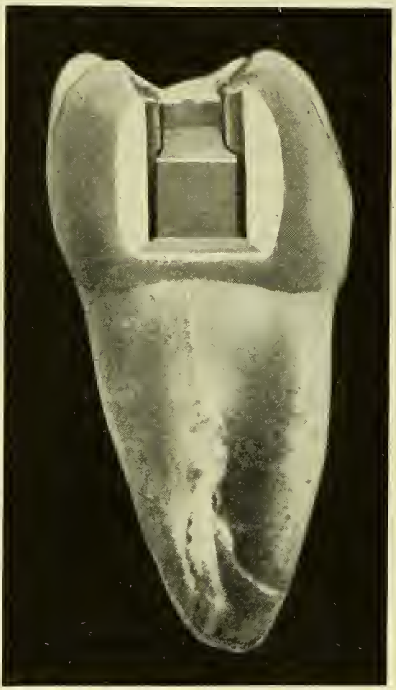


FIG. 649.—Ideal cavity preparation on a lower first molar for reception of a gold inlay.

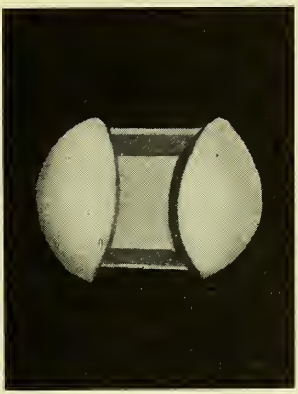


FIG. 650.—M.O.D. preparation.

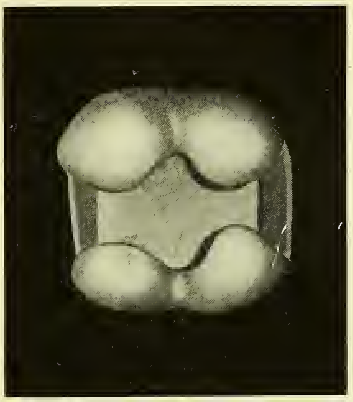


FIG. 651.—M.O.D. preparation.

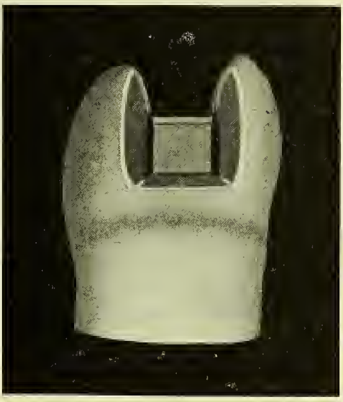


FIG. 652.—M.O.D. preparation.

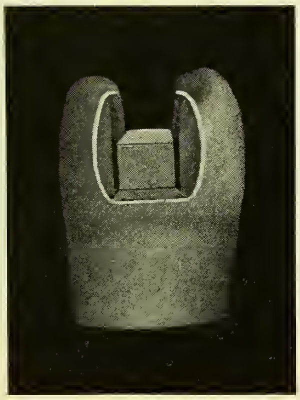


FIG. 653.—M.O.D. preparation.

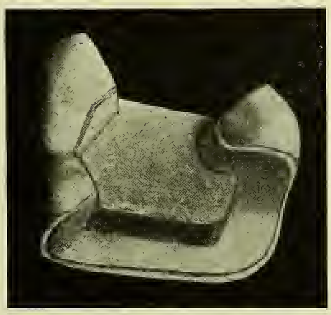


FIG. 654.—Inlay preparation involving removal of a cusp.

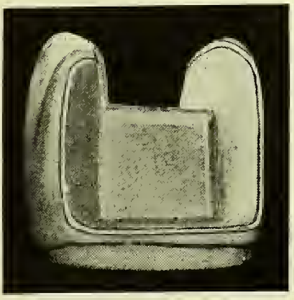


FIG. 655.—Same cavity as shown in Fig. 654, different aspect.

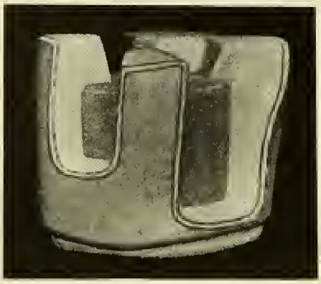


FIG. 656.—M.O.D. preparation with removal of all four cusps.

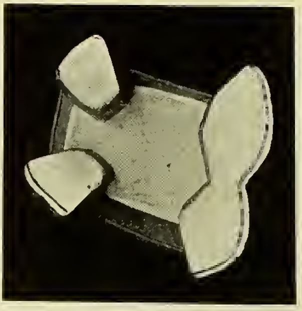


FIG. 657.—Occlusal view of cavity shown in Fig. 656.

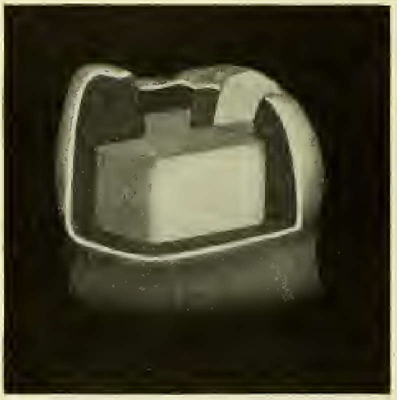


FIG. 658.—Extensive cavity preparation for inlay.

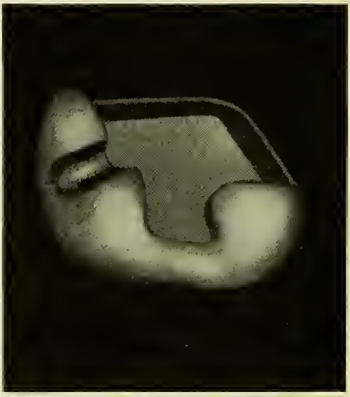


FIG. 659.—Inlay preparation on badly involved molar.

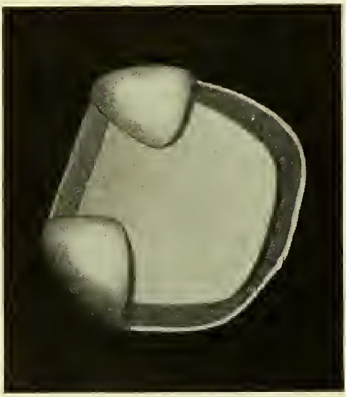


FIG. 660.—Extensive inlay preparation on a molar.

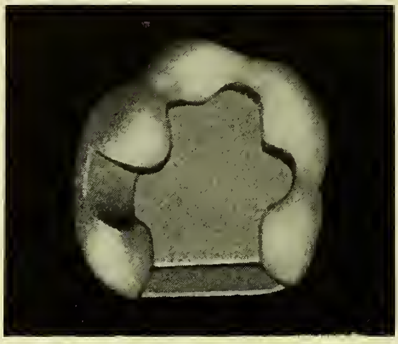


FIG. 661.—Large Class II involving buccal groove.

extending a post into the pulp chamber and canals. The post should be as heavy and as long as practicable.

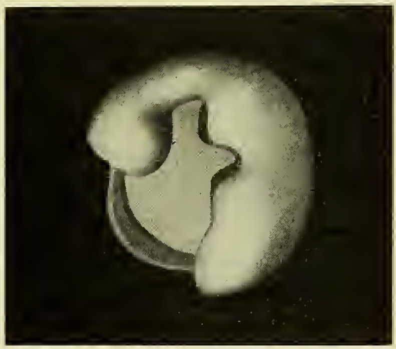


FIG. 662.—Loss of cusp.

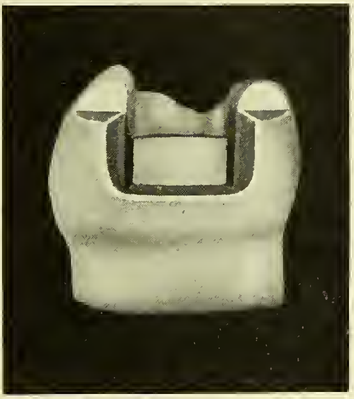


FIG. 663.—Loss of portion of cusps.

CONSTRUCTION OF THE INLAY

The making of the gold inlay may be divided into five steps, each of which must be conducted with great precision and attention to detail. These steps are as follows:

1. Making the wax pattern or model of the inlay.
2. Investing the pattern.
3. Dissipation of the wax from the investment or mold and expanding the mold.
4. Casting the gold into the resultant mold.
5. Finishing and cementing the inlay to place.

Practically all substances expand on heating and contract on cooling. In the construction of the gold inlay, most of the errors arising and misfits resulting in the past have been due to failure to recognize this law and to compensate for the differences in the ratio of expansion and contraction of the wax pattern, the investment, and the gold at the different temperatures at which they are handled. The secret of success in this regard is to keep these materials at as nearly the same temperature as conditions will admit, throughout the process of construction.

In research conducted by the Research Commission of the American Dental Association at the United States Bureau of Standards, sufficient data has been secured to enable the profession, through proper methods, to compensate for the variables incident to thermal changes. This has taken the gold inlay out of the realm of empiricism, which it previously occupied, and placed it on a more scientific basis. Before this result could be obtained improvement in the specifications for inlay waxes, investments and casting golds as formerly manufactured and an increased knowledge of their methods of manipulation, in order to correlate these variables was necessary. As an example, the average contraction of the gold on cooling in the mold is reported by the Bureau as being 1.25%, as a result of which the inlay will be 1.25% smaller than the wax pattern, the mold in which it was cast and of the cavity which it is intended to fit. To prevent this, the shrinkage of the gold must be compensated for by expansion of the investment material. It may be perceived that if investments are used of definitely known ratios of thermal expansion when worked at definite temperatures and with exact methods, the contraction of the gold may be readily compensated for by producing 1.25% expansion of the investment. In order to accomplish this the better manufacturers have modified their formulas to comply with the specifications of the Bureau, as a result of which these materials may in future be used with assurance of producing definite results.

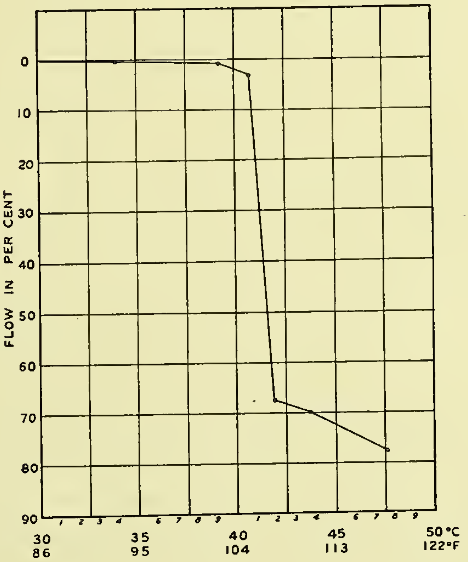
INLAY PATTERN WAXES

A knowledge of the properties of pattern waxes is important. The various waxes used for this purpose may be classified as soft, medium, or hard, depending on the temperatures required to bring them to the plastic or workable stage. These temperatures range from 104° to 122°F. (40° to 50°C.). The harder waxes, which require higher temperatures, although more difficult of manipulation are safer to use, because they are less subject to distortion. It is important that distortion of the wax pattern of the cavity does not occur, else the change of form will be duplicated in the cast gold, and a misfit will be the result.

Qualifications for Inlay Waxes.—Inlay waxes should possess the following qualifications: (1) very low coefficient of thermal expansion; (2) high cohesive property; (3) low tendency to adhere to cavity walls; (4) plasticity at temperatures slightly above that of the mouth; (5) hardness at mouth temperatures; (6) absence of tendency to distortion, breaking before bending; (7) easily distinguishable color; (8) translucence in thin layers; (9) volatility at low temperatures.

A low degree of thermal expansion is valuable because it will not shrink appreciably when cooled to room temperatures. If this property were present to too high a degree, it would be dangerous, because the wax must be warmed to make it plastic and then it must be cooled to allow for carving, removal from the cavity and later handling. A high thermal expansion would be more likely to interfere with the fit of the pattern to the cavity on completion. Sufficient cohesiveness is important, in order that the wax may present compactness while being worked into the cavity and in carving and finishing to cavo-surface angles. Cohesiveness to cavity walls would interfere with ready withdrawal and be likely to produce distortion. Plasticity at low temperature and hardness at mouth temperature, or slightly lower, is desirable in order that the wax may be readily introduced into the cavity at a comfortable temperature for handling and then conveniently chilled to permit of carving and withdrawal without distortion. The wax should break before becoming distorted, else slight degrees of distortion during manipulation may occur without being recognized. The color should contrast strongly with that of the tooth and soft tissues, and translucence when built out over enamel bevels should be apparent, in order that the wax may be readily seen when being carved and finished to cavo-surface angles. Blue, green and brown colors offer the best contrasts. Volatilization or dissipation of the wax from the mold must be accomplished at relatively low temperatures, else the plaster, which is a component of the investment is likely to partially disintegrate. Hence, all of the constituents of the wax should possess low volatility.

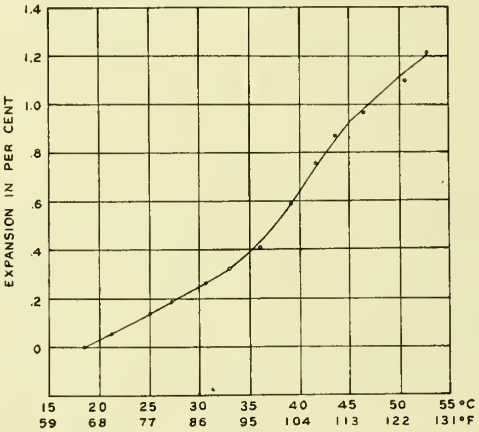
TABLE 1.—FLOW OF INLAY WAX NO. 5



Inlay waxes are usually mixtures of paraffin, ceresin, carnuaba wax, beeswax and oil soluble colors. The physical properties of inlay waxes have been studied and recorded by the Research Commission of the Amer. Dent. Assoc. Some technics of inlay casting formerly depended upon the expansion of the wax to partially compensate for the 1.25% shrinkage of the gold. This is not a scientific procedure because the wax will not expand to any appreciable extent without distortion of the pattern. The most tenable method of casting is one in which high heat expanding investments are used to give castings that compensate for the shrinkage in cast gold without necessitating the expansion of the wax pattern.

An ideal wax for inlays should have a very low coefficient of expansion, for then it would not shrink appreciably when cooled from mouth to room temperature. Modern developments in investing materials have obviated the need of resorting to wax expansion.

Table 2.—Thermal Expansion of Inlay Wax No. 5



Inlay waxes that meet the specifications of the Research Commission of the American Dental Association have a definite volume change for each degree temperature change.

Tables No. 1 and No. 2 show the flow and thermal expansion curves of an inlay wax that meets the A.D.A. specifications.

American Dental Association Specification No. 4. Tentative Specification for Dental Inlay Casting Wax

(Approved July 24, 1930)

I. 1. This specification is for the waxes used as patterns in the production of cast gold inlays. They are essentially waxes and hydrocarbons of the paraffin series. 2. The wax may be furnished as sticks or cones.

II. Material: The wax shall be uniform in quality and free of foreign material.

III. General Requirements: Waxes shall possess the following features: 1. The color shall be such as to facilitate the carving of patterns through contrast with the hard and soft tissues of the mouth. 2. The materials shall soften without becoming flaky. 3. The materials shall trim to a fine margin without appreciable chipping or flaking. 4. The materials shall be capable of being melted and vaporized without leaving solid residues other than carbon.

IV. Detail Requirements: 1. Flow at mouth temperature. Samples 1 cm. in diameter shall not shorten more than 1 per cent in length when subjected to a load of 2,000 gm. for ten minutes at 37.5°C. 2. Softening point. The softening point of the material shall be between 38 and 42°C. 3. Working Range. The material shall soften sharply and a working plasticity shall be obtained at or below 43°C. 4. Thermal expansion. A curve or numerical data shall be supplied with the material which will enable the purchaser to make the proper use of the material in technics requiring wax expansion.

V. Methods of Test: 1. Flow at mouth temperature. Specimens shall be cylinders 10 mm. in diameter and 6 mm. in length. The ends shall be surfaced plane at right angles to the axis. Samples shall be maintained at the testing temperature for at least twenty minutes prior to testing. A load of 2,000 gm. shall be applied for ten minutes, the temperature being maintained at 37.5°C. The change in length shall be calculated in percentage of original length. 2. Softening point. The softening point shall be determined from a curve obtained by plotting values for percentage of flow as obtained by the method outlined in V-1 against variations in temperature. The material shall be considered to have softened when the flow exceeds 5 per cent. 3. Working range. The working range shall be considered the temperature range within which the materials will exhibit a percentage of flow of from 50 to 60 when subjected to pressure as outlined in V-1. 4. Thermal expansion. The thermal expansion characteristics of the materials shall be determined by methods which will insure an accuracy of ±0.05 per cent, up to the temperature at which warpage occurs.

VI. Packing: 1. The minimum net weight of the contents shall be indicated on all packages. 2. Each package shall be marked with a serial number or combination of letters and numbers which shall refer to the manufacturer's records for the particular lot of wax. 3. The date of manufacture (year and month) shall be indicated on the package as a separate item or as a part of the serial number.

VIII. Notes: 1. Manufacturers of waxes may indicate that their products comply with this specification by (*a*) a statement on the package guaranteeing the material contained therein to meet the requirements of this specification, or (*b*) a statement of the physical properties of the wax. In either case, thermal expansion data shall be supplied. 2. The American Dental Association will not assume reponsibility for, or guarantee compliance of, materials so labeled by manufacturers, but will, in event of a dispute between a member of the Association and a manufacturer, act in an advisory capacity and will designate laboratories having equipment for testing waxes, where necessary tests may be made.

Certified Inlay Casting Wax
A.D.A. Specification No. 4
(J.A.D.A., January, 1931)

Wax	Manufacturer or Distributor
Brewster	E. R. S. Brewster
Caulk Blue	L. D. Caulk Company
Maves	The Heidbrink Co.
Kerr Blue—Hard	Detroit Dental Mfg. Co.
Peck's Blue	A. E. Peck Mfg. Co.
Security	Cleveland Dental Mfg. Co.

INLAY INVESTMENTS

Most modern investments used for making the molds for casting consist chiefly of plaster of Paris and quartz (SiO_2), or cristobalite. Plaster acts mainly as a binder. Small amounts of other materials, such as graphite, boric acid, etc. are added to some of them to modify certain of their properties. Setting or hardening of the investments is due to the chemical reaction between the water used in mixing and the plaster of Paris. Most of the investments expand in varying amounts on setting and on being heated, and contract on cooling. A few have the undesirable property of contraction on setting and heating. These dimensional changes will affect the dimensions of the mold and of the final casting. Investments vary in strength, texture and porosity, depending on composition. Insufficient strength is likely to produce a distorted casting, as a result of inability to withstand the pressure of the melted gold when cast forcibly into the mould. Insufficient porosity will interfere with the passage and escape of air or gases from the mould during heating and casting and will likely produce an imperfect casting. Excessive coarseness of texture will be likely to be reproduced on the surface of the casting. The expansion of investments usually increases with increase of plaster content. In most instances, increase of the amount of water used in mixing decreases expansion. Prolonged heating of an investment after it has reached a given maximum temperature has very little effect on expansion and contraction. The usual casting investment shows an average rise of temperature of 5°C. during setting as a result of chemical reaction.

Classification.—The investments on the market were formerly classified into three general types, viz.; 1. low plaster content, 2. high plaster content, and 3. high expansion investments. For exact and scientific work most of these should now be considered obsolete.

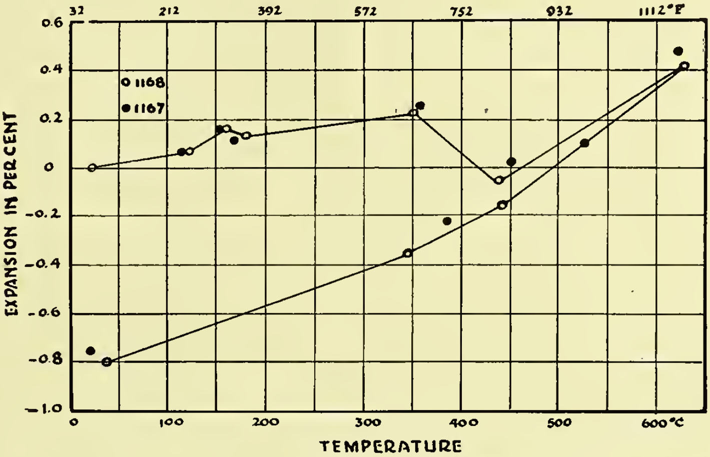


Fig. 664.—Thermal expansion of a low plaster content investment as determined by the U. S. Bureau of Standards.

Low plaster content investment contains about 25% to 35% plaster, the remaining important constituent being Silica. This type expands about 0.2 to 0.3% when heated to 600° to 650°F., contracts when further heated to about 900°F. and slightly expands between 900° and 1,100°F. the latter temperature being red heat. At 1,100°F., the total expansion averages 0.4%. Fig. 664, indicates graphically the expansion and also the cooling contraction (0.8%) of an investment typical of this type as determined by the Bureau of Standards. The cooling contraction is greater in some others of this class. The disadvantages of investments of this first group are (1) that great care is necessary to avoid carrying them, on heating, to the contraction period (650°F. to 900°F.); (2) if carried to higher temperatures, 900° to 1,100°F., it is difficult to maintain them at that temperature and avoid their returning to the contraction period before casting gold into molds made from them; and (3) they lose a great deal of their strength and contract markedly if allowed to cool before casting. These investments have been used in the past for the so-called low heat, slow drying or wax carbonization methods for eliminating wax from the mold.

High plaster content investment consists principally of about 45% to 55% plaster and the balance Silica. These types expand approximately 0.1 to 0.2% when heated to about 600°F. and contract markedly on further heating and on cooling. Fig. 665 shows the expansion and contraction curves of an investment of this class as determined by the Bureau of Standards. Intermittent shrinkage curves in investments are attributed to loss of the water of crystallization at the time the shrinkage occurs. The amount of the shrinkage is largely dependent on the percentage of plaster present. This second type has been used by some in the past for so-called rapid elimination of wax methods and for casting into comparatively cold molds. Since they lose a great deal of their strength, cannot be heated advantageously over 600°F., have low expansion, and contract markedly above that temperature, as well as on cooling, their disadvantages are apparent.

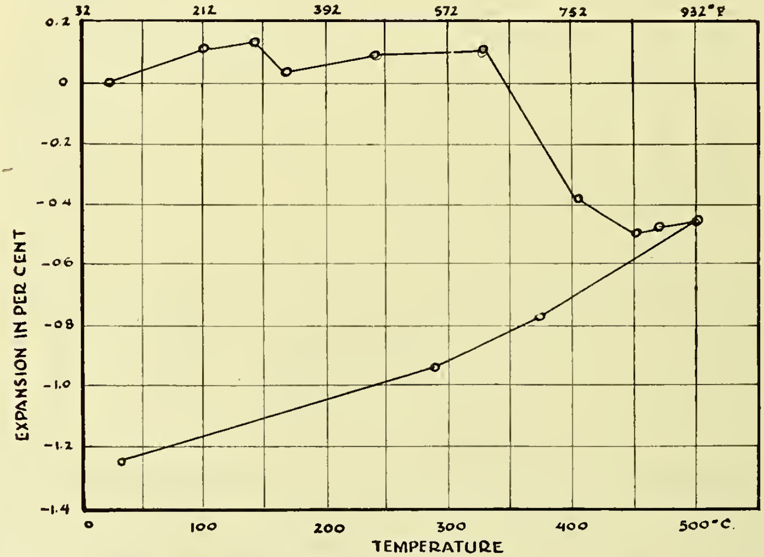


FIG. 665.—Thermal expansion and contraction of a high plaster content investment, as determined by the U. S. Bureau of Standards.

High expansion investments formerly consisted of 25 to 40% plaster, together with silica and 1 to 2% boric acid. This type, more recently introduced, shows greater expansion, porosity, capability of standing heat and greater strength on cooling than the other types. The addition of boric acid increases porosity, thus allowing for escape of air and gases during heating and casting, and assists in increasing tendency to expansion. These investments expand continuously up to red heat, averag-

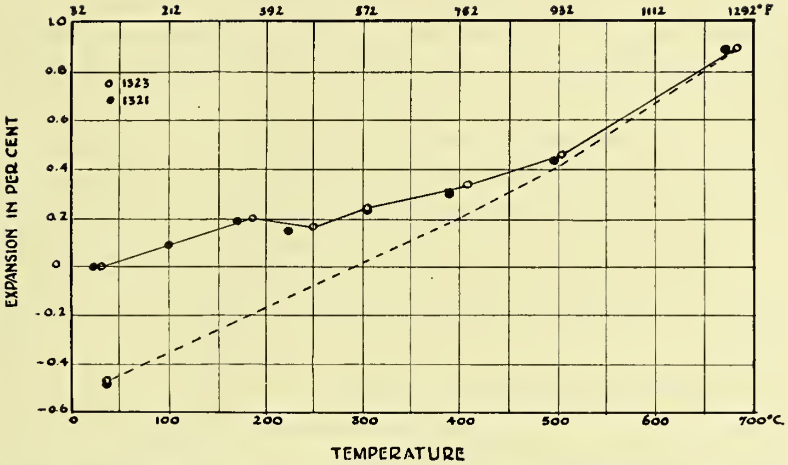


FIG. 666.—Thermal expansion and contraction curves of a high expansion investment, as determined by the U. S. Bureau of Standards.

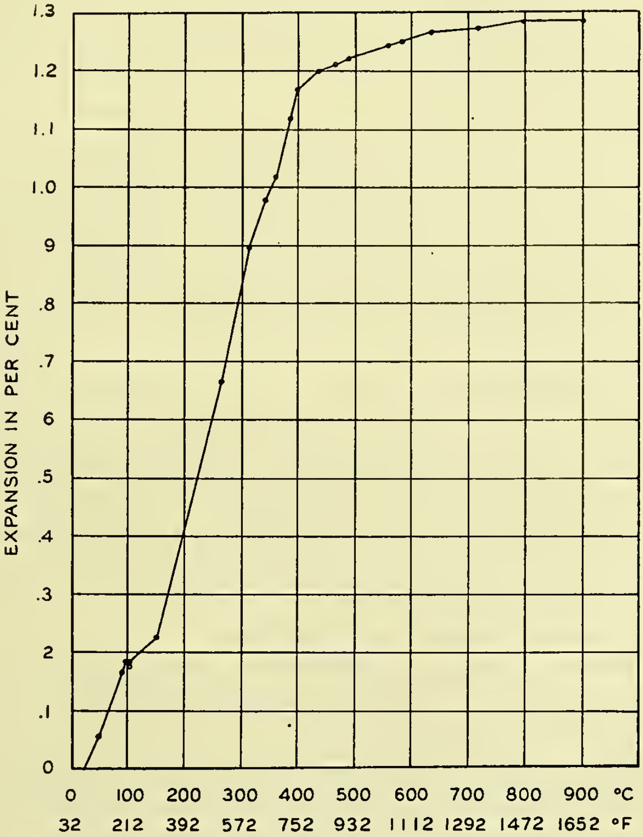


FIG. 667.—Thermal expansion curve, cristobalite investment.

ing 0.8 to 0.9% at 1,100° to 1,200°F. and show practically no contraction until cooling begins. Fig. 666 indicates the expansion and cooling ratio of a prominent investment of this class. Either the slow or rapid method of wax elimination may be used with this type.

Figure 667 shows the thermal expansion curve of an investment containing 25% plaster of Paris and 75% cristobalite. This investment is advocated by the Research Commission of the American Dental Association. "This curve differs from those of the ordinary plaster-quartz investments in that its highest expansion is about 1.25 per cent at 1000°F. and it has practically the same expansion between 1000 and 1600°F. Thus there is a range of several hundred degrees where one could cast and be assured that he would have the maximum expansion. Also, there are no serious depressions in the curve, which has an almost continual expansion at a relatively low temperature as compared with the plaster-quartz investments. Fine castings made at 100 degree C. intervals are shown on the curve at about the temperatures where they were cast. This shows that all of the gold contraction can be cancelled by the investment expansion." (Volland and Paffenbarger, Cast Gold Inlay Technic, Jour. A.D.A., February 1932.)

In using Cristobalite investment an asbestos lining should be inserted in the investment ring. The asbestoes lining should be moistened so that the water content of the investment will not be changed when poured into the ring. The asbestos lining provides an expansion cushion, which permits the major portion of the setting expansion to take place toward the circumference of the ring, instead of toward the pattern, which would result in a distortion.

Master Specification.—As a result of an investigation of the properties of most investment materials on the market and the proposed further standardization of the casting process to correlate the variables in the various materials used, the U. S. Bureau of Standards has prepared a master specification for inlay investments. This has eliminated the majority of the Class I and Class II investments and tends to further improve the characteristics of the last type described. The chief features of this specification are as follows, viz.:

1. A minimum setting expansion for a 24 hour period of 0.05%.

2. Minimum thermal expansion when heated from room temperature to 700°C. (1,300°F.), 0.7%.

3. During heating no shrinkage below the original length at room temperature is allowable above 390°F., (200°C.). Not more than 0.15% intermittent reversal of expansion below maximum length at lower tem-

perature is allowable above the temperature of 390°F., and this must be ultimately compensated for.

4. The material must show a minimum compressive strength of 350 pounds to the square inch.

5. The time of set shall be not less than 5 nor more than 30 minutes.

6. Ninety-five per cent of the investment must be capable of passing through a 100 mesh sieve, 80 per cent through a 200 mesh sieve and all of it through a 30 mesh sieve.

7. The material must be satisfactory in all general features.

The following is the list of certified inlay investments as of June 24, 1935

SECOND SURVEY OF INVESTMENTS
June 24, 1935

Investment	Manufacturer or Distributor
Coecal Inlay	Coe Laboratories, Inc.
Coecal Universal	Coe Laboratories, Inc.
Kerr Cristobalite-Inlay	Detroit Dental Mfg. Co.
Kerr No. 3	Detroit Dental Mfg. Co.
Ransom and Randolph Gray	The Ransom & Randolph Co.
Ransom and Randolph Green	The Ransom & Randolph Co.
Ransom and Randolph X-45	The Ransom & Randolph Co.
S. S. White Inlay No. 20	S. S. White Dental Mfg. Co.

Correlating Variables.—With a compliance to these general specifications by the manufacturers and a knowledge of the definite thermal expansions as indicated on the label for each product, the casting shrinkage of gold is easily compensated for by proper methods of manipulation of these investments. It is now obvious that expansion of investment to definitely known amounts must be accomplished to produce the desired result.

Expansion of the investment is produced by mixing and heating at definite temperatures. After elimination of the wax, the expansion of the mold is maintained by casting into it while hot and before cooling contraction begins. The haphazard method of casting may be eradicated by using inlay investments which comply with the Amer. Dent. Assoc. specifications.

Bibliography

Bureau of Standards Research Paper no. 32, Dec. 1928.

Souder, Wilmer and Sweeney, Wm. T.: Tentative specifications for dental casting investment, Jour. Amer. Dent. Assoc., May 1930, p. 780.

Taylor, Paffenbarger and Sweeney: Dental inlay casting investments, Jour. A.D.A., Dec., 1930, p. 2266.

CHAPTER XXI

THE CAST GOLD INLAY (*Continued*)—CASTING GOLDS—TECHNIC FOR CONSTRUCTING INLAYS—THE DIRECT AND INDIRECT METHODS

CASTING GOLDS

Twenty-four karat gold was used for some time following the introduction of the modern methods of casting gold inlays. It was soon found that in many cases it was much too soft to resist the stress of mastication or of interproximal wear at the contact points. It previously has been mentioned that in Doctor Black's experiments an inlay of pure cast gold will have a greater density or specific gravity when weighed in water than a hammered gold foil filling; but that regardless of this, a properly condensed gold filling is harder and resists stresses to a higher degree. It must be recognized, then, that density or specific gravity, hardness and strength are separate physical properties.

Now, alloys of gold are largely used in inlay work, because it is found that castings made of these are nearly or quite as strong, or even stronger and harder than many cohesive gold fillings, depending on the proportions of the constituents of the alloy. There is a great danger in the use of very hard alloys for this purpose, either for single inlays or bridges, in that other occlusal surfaces may wear more rapidly than the teeth in which they are placed and gradually produce traumatic occlusion of the inlayed teeth and its attendant evils.

For single inlays, the softer alloys should be used, depending on the size and location of the cavity, the strength of the bite and the evidences of occlusal wear in the mouth. For abutments and where a number of inlays must be inserted in cases where it is necessary to open the bite, harder alloys should be resorted to. However, under these circumstances, the danger of their use, just mentioned, should be constantly borne in mind.

Properties of Casting Golds.—Many of the properties of gold have previously been discussed in connection with its use as a filling material. It possesses additional characteristics when pure or when alloyed, which bear on its use for inlay construction. The melting or fusing point of pure gold is estimated at 1,063°C. (1,945°F.). The boiling point of gold has not been accurately determined, but it is probably about 2,240°C. Gold is volatile in air at far lower temperatures. Rose, of the Royal British Mint states that 0.5 grams of gold loses half its weight in an hour when heated on a cupel to 1,300°C. Schnabel gives the volatility of gold as between 1,045°C. and 1,075°C. Much loss of gold from heating to extremely high temperature is due to its passing off as spray and not to volatilization. Alloys of gold and copper volatilize more readily than pure gold. Gold and silver alloys volatilize less readily than those of gold and copper. Platinum has a very slight effect in increasing the volatility of gold. The repeated or long continued heating to a very high temperature of gold alloys results in the segregation of the less volatile and the higher weight metals to the surface, with an unbalancing of the alloy. Metals of low fusing points will volatilize out first and markedly change the formula, if the alloy be repeatedly subjected to very high temperature. However, fusing to proper temperatures, melting the alloy just to the point where it flows freely and casting at once will produce practically no volatilization, segregation or unbalancing of the constituents. As a result, inlay golds may be used several times without fear of much disturbance of their balance. However, when used a second or third time, it may be advisable to add to the used ingot, as a matter of safety, an additional amount of fresh alloy. After a few times use, it will be advisable to discard it. Whenever ingots are used more than once, they should be pickled in acid and thoroughly cleansed before melting and casting. The fusing points of the metals most used in compounding gold alloys are as follows:

MELTING POINTS OF ELEMENTS USED IN GOLD CASTING ALLOYS

Element	Melting point	
	Centigrade	Fahrenheit
Gold	1,063°	1,945°
Copper	1,083°	1,981°
Silver	960°	1,760°
Platinum	1,755°	3,191°
Palladium	1,549°	2,820°

Chemical Composition and Uses.—A chemical analysis made by the Bureau of Standards of many gold alloys formerly on the market revealed that the formula of many was complex and largely empirical. The following table indicates the chemical composition of some of the older casting gold alloys as determined by the Bureau of Standards.

CHEMICAL COMPOSITION OF A FEW CASTING GOLDS (PER CENT BY WEIGHT)

Alloy	Gold	Silver	Copper	Platinum	Palladium	Iridium	Zinc	Uses
1	78.0	10.0	5.9	6.1	....	0.1	....	Hard inlays
2	67.0	16.8	12.2	3.92	....	0.05	....	Hard inlays
3	81.1	11.0	4.0	3.75	....	0.10	....	Clasps or abutments
4	76.3	5.1	9.8	8.00	....	....	0.82	Three-quarter crowns
5	79.6	4.5	8.0	7.80	....	0.03	0.06	Carmichael abutments
6	81.8	7.2	7.2	3.95	....	....	....	Carmichael, ¾ crowns, etc.
7	67.8	16.5	8.9	2.96	2.82	0.08	0.94	Hard inlays, etc.
8	83.2	8.4	8.3	....	....	....	....	Hard, dense inlays, etc.
9	89.8	0.04	10.0	0.08	....	....	....	Inlays
10	91.7	7.8	0.5	....	....	....	....	Inlays
11	91.7	4.6	3.7	....	....	....	....	Cast dentures
12	75.0	21.8	3.2	....	....	....	....	Cast dentures

The numbers given the alloy are those of the author and not of the Bureau of Standards. The small percentage of Iridium and Zinc are probably accidental impurities. Alloy number 8 contained 0.18% of tin as an impurity, not indicated in this table. The uses mentioned were those advocated by the manufacturers. These alloys were representative of the composition and uses of many of the casting golds formerly on the market.

Copper, silver and platinum are the principal metals used for alloying gold for use for casting single inlays in Operative Dentistry. Copper produces a darker color and greater hardness than silver. The latter lightens the color of the alloys in proportion to the amount used and also hardens it. Inlay golds should be selected for use, depending on the purpose they are intended to serve and on the basis of their chemical constituents and working properties, rather than empirically on the basis of their trade name.

Porosity.—Cast gold alloys show porosity with the presence of voids or spaces to a greater or less extent, when examined under the microscope. Porosity is usually present in greatest amounts in sections made adjacent to the sprue. Porosity is attributed to (1) localized shrinkage, due to different rates of cooling in different parts of the casting; (2) occluded gases formed during casting; and (3) inclusion of metallic oxids. With the proper use of the reducing flame, and exclusion of imperfect combustion products from impure gas flames, the formation of metallic oxids may be largely eliminated as a cause of porosity. Porosity adjacent to the sprue from localized shrinkage, which is frequently present is easily eliminated by providing a special reservoir or chamber close to the sprue, which will feed additional melted gold to the casting. It may also be prevented through the use of large, short sprues. Oxygen and hydrogen gases occluded into the body of the gold during the casting are the most frequent causes of porosity and the most difficult to avoid or eliminate. Of these, oxygen is the most frequent offender.

Densities and Brinell Hardness.—The Bureau of Standards conducted tests to determine differences in density, hardness, and microstructure of cohesive gold fillings and soft cast gold inlays. Six cohesive gold fillings were condensed into steel molds one-eighth inch square and three-sixteenths inches deep by prominent dentists co-operating with the Bureau. The volume of the test filling was calculated from micrometer measurements of its linear dimensions. The density was then determined, not by the usual specific gravity test, but by dividing the weight of the filling by the volume. The values obtained by this method are slightly lower than those resulting from weighing in media of two different densities, such as air and water. In this instance the difference in density was due largely to irregularities on the surface of the fillings, due to imperfect adaptation to cavity walls. The densities

TABLE 15.—PROPERTIES OF FOIL FILLINGS AND SOFT INLAY GOLDS

Foil fillings			Cast-inlay golds	
Sample No.	Density	Brinell hardness number	Material	Brinell hardness number
	g./cm.^{3}			
1	17.0	[1]36	24-carat gold[3]........................	27
2	17.3	50		
3	14.2	[2]18	Alloy XXVII; 22 carat gold (0.5% copper)................................	32
4	16.8	51		
5	18.2	61	Alloy XXVIII; 22 carat gold (3.7% copper)................................	54
6	19.0	60		
Average..	17.1	46		

[1] Brinell hardness of different spots varied from 22 to 46.

[2] Brinell hardness of different spots varied from 13 to 26.

[3] Density of 24 carat cast gold is 19.3 g./cm.^{3} (Smithsonian Physical Tables, 7th ed., p. 110).

and Brinell hardness are indicated in Table 15, taken from Bulletin 32 of the Bureau.

By referring to this table it will be observed that there are very noticeable variations with the different fillings tested. The densities range from 14.2 g. to 19.0 g. per cubic centimeter, and Brinell hardness from 18 to 61. Samples No. 1 and 3 were quite variable in hardness in different localities, due to differences in amount of condensation. The average values for the six fillings are 17.1 g. per cubic centimeter for density and 46 for Brinell hardness. Comparing these values it is seen that the gold foil fillings tested were much harder than inlays cast from 24 carat gold or of those cast from 22 carat gold containing 0.5% copper and nearly as hard as those cast from 22 carat gold containing 3.7% copper. Some of the individual fillings, owing to more perfect condensation were much harder than either of the inlays. The density of the fillings, as obtained by the method utilized was less than 24 carat gold, which is given by the Bureau as 19.3 cm.^{3} These figures emphasize the facts previously stressed that density and hardness must be considered as separate properties; that well condensed gold fillings are harder than cast inlays of pure gold or of alloys containing 0.5% copper and that perfection of adaptation to cavity walls is of more importance than either.

Casting Shrinkage.—During the casting process the contraction of gold occurs at three different stages, viz. (1) contraction of the liquid metal from the time it is fused until it enters the mold; (2) contraction from the time it enters the mold until it solidifies or freezes; and (3) contraction from the time it freezes until it reaches room temperature. Weston A. Price in the Dental Cosmos for March 1911, page 265 reported the linear contraction of gold in passing from the liquid to the solid state as 1.46%. The Bureau of Standards reports the thermal contraction of 24 carat gold from the melting point, 1,063°C. (1,945°F.) to 25°C. (77°F.) as 1.76%, while it gives the thermal contraction of an alloy of gold 90 to copper 10 parts as 1.62% with the same temperature ranges. The casting shrinkage of a gold-copper alloy (90 gold, 10 copper) when cast into a mold under conditions similar to those used in casting inlays, it reports as 1.25%. This latter figure may be taken as the average casting shrinkage of gold alloys as used for casting inlays. Differences in the temperature at which the metal is fused and cast and the temperature of the mold affect the results very slightly, if any.

The difference between the normal thermal contraction of casting golds and the casting shrinkage or contraction may be accounted for in two ways, viz. (1) Friction or interlocking between the cast metal and the walls of the mold, preventing full or normal shrinkage, and (2) Maintenance of the casting pressure, with the addition of necessary fluid metal from the crucible and sprue, to prevent full thermal contraction during the solidification of the casting. If part of the metal of the mold solidified before the metal in the sprue freezes, the shrinkage of the solidified portions would be partly compensated for by the addition of fresh metal under pressure from the sprue. In its investigation of the casting process, the Bureau of Standards briefly summarized in Bulletin 32 its findings as follows:

Summary of the Bureau.—"The porosity of internal voids prevalent in dental gold-alloy castings was found to be due largely to localized shrinkage, or occluded gases, or both. The usual concentration of these defects adjacent to the sprue may be avoided by the use of a short sprue of large diameter, or by providing the mold with a chamber close to the pattern and large enough to supply molten metal to the casting as it shrinks during solidification."

"Tests for segregation of the constituents of gold alloy castings indicated that no serious defects from this cause are to be expected in the ordinary dental casting processes."

"It was found that the selective loss of constituent metals or the 'unbalancing' of the composition of gold alloys caused by melting is negligible when the melting is done with reasonable care. If the alloys are heated to excessively high temperatures, loss of base metals is likely to occur."

"The net linear casting shrinkage of an alloy containing 90% gold and 10% copper was found to be approximately 1.25%. No significant variations in this value caused by variations in the temperature of the metal when cast, the temperature of the mold, or the casting pressure were observed. Measurements made on a number of other alloys indicated that no large variations in net shrinkage, caused by the variations in composition of the usual casting golds, is to be expected."

"Two types of roughness of surface of dental castings, causing inaccuracies of dimensions, were observed. It was found that one of these was due to air bubbles in the investment and the other to the collection of water on the surface of the pattern during or soon after investing. The first type can be largely eliminated by thorough mixing of the investment, preferably with a mechanical mixer, or by mixing the investment in vacuum. The latter type can be largely eliminated by painting the

Certified Inlay Casting Golds
A.D.A. Specification No. 5
(J.A.D.A., January, 1932)

Alloy	Type*	Manufacturer or Distributor
Chilcast No. 1	A	Vernon Benshoff Co.
Chilcast No. 1-A	B	Vernon Benshoff Co.
Chilcast No. 2	C	Vernon Benshoff Co.
Chilcast No. 2-A	B and C	Vernon Benshoff Co.
Chilcast No. 3	C	Vernon Benshoff Co.
Coe 1	A and B	Coe Laboratories, Inc.
Coe 2	B and C	Coe Laboratories, Inc.
Coe 3	C	Coe Laboratories, Inc.
Crown No. 1	A	Patterson-Hettinger Co.
Crown No. 2	B	Patterson-Hettinger Co.
Crown No. 3	C	Patterson-Hettinger Co.
Deetwo Light	A	Thomas J. Dee & Co.
Deetwo	B	Thomas J. Dee & Co.
Deesix	C	Thomas J. Dee & Co.
Goldsmith Inlay No. 1	A	Goldsmith Bros. S. & R. Co.
Goldsmith Inlay No. 2-Medium	B	Goldsmith Bros. S. & R. Co.
Goldsmith Inlay No. 3-Hard	C	Goldsmith Bros. S. & R. Co.
Jelenko Alboro Inlay	C	J. F. Jelenko & Co., Inc.
Jelenko Durocast	C	J. F. Jelenko & Co., Inc.
Jelenko Inlay Gold	B	J. F. Jelenko & Co., Inc.
Jelenko Platin cast	B	J. F. Jelenko & Co., Inc.
Jelenko Special Inlay	A	J. F. Jelenko & Co., Inc.
K Inlay	A	Patterson-Hettinger Co.
Knapp No. 1	A	Patterson-Hettinger Co.
Knapp No. 2	B	Patterson-Hettinger Co.
Knapp No. 3	C	Patterson-Hettinger Co.
Ney-Oro A	A	The J. M. Ney Co.
Ney-Oro A-1	B	The J. M. Ney Co.
Ney-Oro B	C	The J. M. Ney Co.
Ney-Oro B-2	C	The J. M. Ney Co.
No. 1 Hard Inlay	B and C	Patterson-Hettinger Co.
No. 2 Cast Inlay	A	Patterson-Hettinger Co.
No. 9 Cast Gold	C	Patterson-Hettinger Co.
Spyco Hard	B	Spyco Smelting and Refining Co.
Spyco Soft	A	Spyco Smelting and Refining Co.
Spyco No. 6	C	Spyco Smelting and Refining Co.
S. S. White No. 2	A	S. S. White Dental Mfg. Co.
S. S. White No. 1	B	S. S. White Dental Mfg. Co.
S. S. White No. 13	C	S. S. White Dental Mfg. Co.
S. S. White No. 31 Metalba	B	S. S. White Dental Mfg. Co.
Stern No. 2847	C	I. Stern and Co.
Stern No. 3290	B	I. Stern and Co.
Stern No. 3337	B and C	I. Stern and Co.
Stern No. 3375	A	I. Stern and Co.
Stern No. 3441	C	I. Stern and Co.
Stern No. 3465	B and C	I. Stern and Co.
T	B	Patterson-Hettinger Co.
TT	C	Patterson-Hettinger Co.
Tinker No. 1	B	Spyco Smelting and Refining Co.
Tinker No. 1H	C	Spyco Smelting and Refining Co.
Tinker No. 2	C	Spyco Smelting and Refining Co.

* Relative hardness: A—Soft; B—Medium; C—Hard.

pattern with a thin coat of investment and then sprinkling this coating with dry investment powder."

In a later publication, entitled "Inlay Casting Golds: Physical Properties and Specifications," which appeared in the Journal of the American Dental Association, January, 1932 the Research Commission and the Bureau of Standards reported further and more extensive research on inlay casting golds, and divided them into three groups: A, soft, B, medium and C, hard inlay golds. As a result of these studies a specification was presented, the details of which are herewith summarized as follows:

SPECIFICATION NO. 5-A.D.A. INLAY GOLDS (GOLD COLOR)

Type	Gold and Platinum Group Metals % Min.	Silver % Min.-Max.	Brinell Hardness No. Min.-Max.	Percentage El. 2″ Ga. lgth. % Min.	Strength Yield Pt. Lbs./Sq. in. Min.	Fusion Temp. Deg. F. Min.
Soft A	83%	3 12	40 75	18	......	1,725
Medium B	78%	0 15	70 100	12.0*	22,000	1,650
Hard C	78%	0 15	90 140	12.0*	27,000	1,650

* This value shall be reduced ½ of 1 % for each 1 % of Platinum group metals in the alloy. 8 % shall be the minimum elongation allowed for any alloy.

Those Inlay Casting Golds meeting this specification at the present writing are herewith presented. See page 604.

TECHNIC FOR MAKING GOLD INLAYS

Since the introduction of Taggart's method, many investigators have presented modifications, special technics, and appliances of their own design for the casting of inlays, crowns, bridges and dentures. Prominent among these earlier investigators were C. S. Van Horn,[1] E. T. Tinker,[2] Emory C. Thompson,[3] R. H. Volland,[4] Geo. M. Hollenbeck,[5] Albert P. Grunn,[6] Herman A. Marves,[7] and F. S. Meyer.[8] The technic herewith presented is a further development of the work of these pioneers and others, and is based on the scientific findings of the Research Commission of the A. D. A. at the U. S. Bureau of Standards.

There are three general processes of inlay construction, known as (1) the direct, (2) the indirect and (3) the direct-indirect methods. Each of these has its advocates. All three have certain advantages and special indications for use, depending on circumstances.

THE DIRECT METHOD

Making the Wax Pattern.—The pattern for the inlay is obtained by heating the wax, forcing it into position in the cavity, molding it to proper form, chilling it and withdrawing it from the cavity. The wax must be warmed to a temperature at which it becomes soft and plastic, usually 104 to 122°F., depending on composition. It may be heated over an open flame or in warm water of the proper temperature, care being taken not to melt it. When softened, it is molded between the thumb and finger into cone shape. The point of the cone should be small enough to reach the bottom of a simple cavity or the gingival wall of proximal cavities. It should be molded into U shape for M. O. D. cavities. Before insertion, the point of the cone should be again warmed over the flame to soften it, while the base of the cone remains still soft, but resistant enough to act as a plunger in forcing the wax into all parts of the cavity.

In simple cavities with four surrounding walls, this is easily accomplished. In ordinary proximo-occlusal and proximo-incisal cavities the thumb and forefinger, placed to the labial or buccal and lingual sides, will prevent the wax from squeezing out into the embrasures, while the proximating tooth will prevent its exit proximally. In M. O. D. cavities, in cavities in badly broken down teeth, and in those where the proximating tooth is absent, the use of a 36 gauge copper band or a tied matrix trimmed to form and previously oiled, will often be of service in holding the wax into position. When the matrix is not necessary, the softened wax is carried into place and forced tightly in position, so that it is brought into perfect adaptation to all the walls of the cavity, all margins are covered and a sufficient excess is left for carving to form. If the matrix is used, it is lubricated to prevent the wax from clinging to it, placed in position and the wax forced into it as in the previous instance. After the wax has hardened the matrix is removed. If a band matrix is used, it must be split and bent away from the wax. In some instances the tied matrix may be removed without disturbing the wax; in others the wax will come away with the matrix. In the latter case the matrix should be removed, the under surface of the pattern slightly warmed, again forced to place and perfectly adapted.

In all cases, after the wax is forced into position in the cavity, *continuous pressure* should be maintained on it by the thumb or finger until it hardens. The wax should be held under pressure until it returns to mouth temperature, usually three or four minutes. This pressure is maintained to prevent the contraction of the wax and to lock its molecuaol tension in the new position which it has assumed on being forced into the cavity. If the wax pattern was made to fit the cavity at 104°F. and allowed to cool without pressure it would be too small by about 0.7 to 0.8%, depending on the wax used; hence the necessity for maintaining pressure and chilling until hard.

As soon as the wax has cooled it should be carved to form, all excess removed and its surface polished with silk tape if on proximal surfaces. On other surfaces it should be smoothed and polished with a cotton pellet moistened in mouth temperature water. Figs. 668, 669 and 670. The patient should not be allowed to bite forcibly into the wax, for fear of destroying the fit of the pattern to the cavity. If near the end of the carving process, it is felt necessary to test the occlusion, the *surface* of the wax may be slightly warmed with a warm burnisher and the patient allowed to close into it carefully without disturbing the adaptation of the hard wax in the body of the pattern. The pattern should be made as perfect and as smooth as possible, else, when it is duplicated in gold, much trimming of the gold will be necessary. Instruments for carving the wax are illustrated in Figs. 671 and 672. In addition to these, explorers number 6, 11, 12, 17 or 23 and sharp Black knives will be useful for carving gingival and proximal portions. Floss silk or number A silk will be valuable for passing between the contact point and the proximating tooth. Also tracing cloth or silk strips for polishing the proximal portion may be useful.

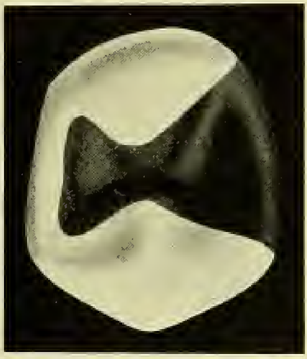


Fig. 668.—Wax pattern completed in a Class II cavity and ready for withdrawal.

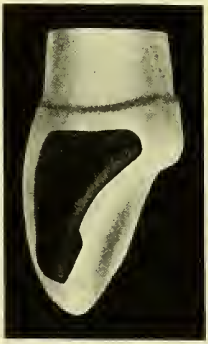


Fig. 669.—Completed wax pattern in cuspid.

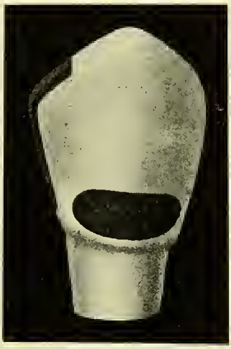


Fig. 670.—Wax patterns.

For carving and finishing a proximo-occlusal pattern the order of procedure should be as follows: viz: (1) carve the occlusal surface with the wax carvers; (2) carve the embrasures and the slope of the marginal ridge toward the contact point with the explorers, the carving instru-

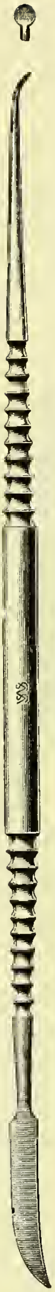


FIG. 671. LeCron inlay carver.

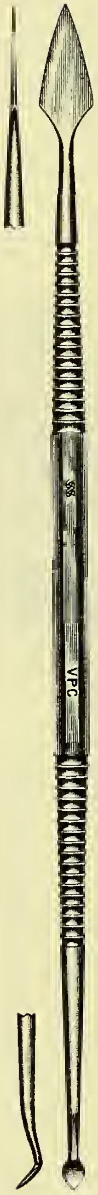


FIG. 672. Vehe inlay carver.

ments or the Black knives; (3) carve the gingival portion up to, but not including, the contact point with the same instruments; (4) pass the silk floss or silk thread "A" carefully past the contact point, holding it against the approximating tooth; (5) then after its removal carry in the silk strip or tracing cloth and with it polish the entire proximal surface. For proximo-incisal patterns the procedure is similar. In these, usually the lingual surface should be trimmed first, when a finger may be placed in such a position as to assist in holding the wax in place. Then the trimming of the lingual embrasure, the incisal surface, the labial embrasure, the gingival portion, the contact point and the final polishing with the tracing cloth should follow in the order mentioned. On completion, the pattern should have been carved to proper anatomical form and occlusion and should perfectly fit the cavity walls and margins. During the process of trimming, the debris should be washed away with water near mouth temperature. Wax patterns should never be suddenly or considerably chilled with cold water. Neither should they be sprayed or swabbed with alcohol, chloroform or acetone. On completion, the mouth should be flooded with room temperature water. Now the pattern should be carefully withdrawn in the proper line of exit to prevent distortion of the wax. For this purpose, a sprue wire may be inserted into the wax at a convenient location and the pattern gently lifted out. In simple cavities the wire may be inserted in the center of the pattern; for proximo-occlusal cavities, between the marginal ridge and the contact point; and for M. O. D. or M. I. D. cavities near the center of the occlusal or incisal step respectively. For this purpose the sprue should be held in the hand, one end slightly heated in the flame and then carefully inserted into the wax. The wire must not be heated too much, else the pattern may be melted, or distorted. It should be attached in the center of the pattern for simple cavities, between the marginal ridge and the contact point for Class II, at the angle of Class IV and near the center for M. O. D. or M. I. D. cavities. If convenient, an assistant may immediately chill the sprue wire and the softened wax with cotton dipped in room temperature water, before removal. Sprue wires should average from 15 to 17 gauge and be tapered to a point to lessen the risk of over-heating the pattern on insertion. Large and short sprues are better, since on removal they leave a larger opening for the entrance of the gold in casting.

Before dismissing the patient, the cavity should be carefully sealed with base-plate guttapercha to protect it from the oral secretions and to prevent hypersensitivity.

Investing the Pattern. General Principles.—The wax pattern should be invested at once, to prevent temperature changes and marring, which might occur from allowing it to lie unprotected in the laboratory. Before doing this, it should be carefully washed with a soft camel's hair brush or water syringe and soap and water at room temperature, to remove saliva, blood or mucous deposits from its surface. A bottle of water should be kept in the laboratory at all times and away from a window, to be used for work on wax patterns and investments. Water from a cold water faucet should not be used, since it varies in temperature at all seasons of the year, and will be likely to contract the wax. A better plan is to make a fairly thin mix of investment in water at room temperature and coat the wax pattern with it by means of a sable hair brush. After thoroughly coating it, wash off the investment with room temperature water in a water syringe. If necessary, repeat the procedure until oily or other matters are thoroughly removed, then remove any water labules adhering to the pattern, with air from a chip blower.

To prevent the too rapid cooling of the metal in casting and to avoid as far as possible porosity or voids in its interior or on its surface, a large, short sprue should be used or provision made for a separate chamber in the investment, close to the pattern and large enough to supply additional melted gold to the casting as it shrinks during freezing. Localized shrinkage and porosity often occur in the solidified gold after casting, particularly in the region close to the attachment of the sprue. Where small or large sprues are used, this may be prevented by attaching to the sprue a short distance from the pattern, a ball of wax about one-fourth the size of the pattern. When the wax is dissipated from the mold, this will leave an accessory chamber which will be later filled with melted gold to be fed to the mold. If desired, a small length of wax also may be run along the sprue from this ball and extending to the pattern at the attachment of the sprue, thus enlarging it to 12 or 13 gauge in this portion. Fig. 673. The pattern is now ready for investment.

Technic of Investing.—Choose any of the investments which meet the Amer. Dent. Assoc. Specifications. The amount of water and investment necessary for a proper mix is indicated on the container by the manufacturers. The water and investment should be accurately weighed, since the consistency of the mix has a definite relationship to the setting and thermal expansion. The thicker the mix the greater will be the setting and thermal expansion, and the smoother the finished casting. Place the investment and water in a clean dry plaster bowl.

Spatulate thoroughly with a mechanical spatulator for about 100 turns, or with a plaster spatula until a homogenious mass of a thick creamy consistency is obtained, free from air bubbles. A mechanical spatulator produces the best results. Fig. 674. Before mixing the investment cut a piece of asbestos 1/16 of an inch thick and line the entire inner surface of the investment ring. The asbestos allows for setting expansion, and prevents too rapid cooling of the investment before it is cast into. With the sprue inserted into the sprue former held in the left hand, coat the pattern with the investment by means of a fine pointed sable hair brush, pushing the investment ahead of the point of the brush. This procedure forces the air ahead of the investment and prevents trapping of air bubbles, produces closer adaptation of the investment to the pattern and results in smooth castings, free from nodules on the surface. Do not touch the pattern with the brush, or fine margins of the wax may be damaged. Build the investment up into a mound, covering the pattern to a thickness of 1/8 inch and extending over the sprue to the crucible former. If the investment is mixed too thin, an excess of water is likely to accumulate on the surface of the wax pattern and produce roughness of the surface of the gold after casting. If this is feared, a small amount of dry investment powder may be sprinkled on the investment after a thin coating has been painted on to the pattern and before the entire thickness of investment has been applied. In this way, the excess water will be absorbed and the roughness largely eliminated. The ring is now vibrated full of investment. The pattern is then gently vibrated into the investment-filled ring until the sprue former base is seated.

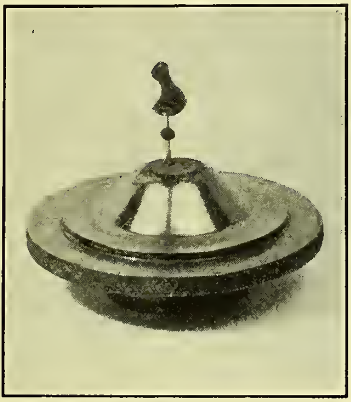


FIG. 673.—Wax pattern showing sprue wire with small ball of wax attached, and mounted on sprue former, or base of investment ring.

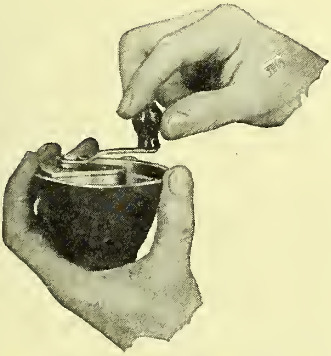


FIG. 674.—Mechanical spatulator.

The investment should now be allowed to set for at least thirty minutes, when it is ready for elimination of the wax from the mold under the influence of heat. Fig. 675.

Elimination of the Wax.—With modern accepted investments, which may be subjected to high temperature without contraction or disintegration, elimination of wax may readily be accomplished in 90 minutes.

The best device for wax elimination is a gas or electric oven with definite thermostatic control. Numerous devices of this type are on the market. In the absence of a special oven with thermometer attachment, a gas burner with a muffle may be used. If this is not available, a metal plate about four inches square may be placed over a Bunsen burner, and a few pieces of wire netting, to permit circulation of air, laid over this, on which the invested pattern may rest. The mercury end of a thermometer may be enclosed in investment material in a casting ring and used to determine heating temperatures.

Fig. 675.—Wax pattern invested.

Technical Procedures.—After the investment has been given thirty to forty-five minutes to set, the crucible former, or base should be carefully pried away from the investment ring. On its removal, the end of the sprue former will be seen protruding from a concave base of investment material, which has been formed by the convexity of the crucible former, and into the concavity of which the gold is to be forced after fusing. The sprue former should now be grasped with a pair of flat-nosed pliers, which have been slightly heated in a flame. After waiting a few moments to allow the heat from the pliers to warm the sprue wire and soften the wax of the pattern in which it is embedded, the sprue should be slightly rotated to loosen it, when it is carefully withdrawn, to avoid breaking or marring the investment. In doing this, the investment ring should be held with the crucible end downward to prevent any loosened particles of investment from dropping into the mould. If a gas burner is used, now lay the inlay ring on its side with its crucible end forward on top of the oven. Place a Bunsen burner underneath, with its flame adjusted to about ¼ capacity, and dry the investment at a temperature of about 300°F. for about twenty minutes. If the heating arrangement provides a muffle, place the inlay ring inside the muffle or oven in the same position as before, and gradually raise the heat by turning up the burner to ½, and then to full capacity, till a temperature of 900°F. is reached. If a muffle is not available the heating is carried out in a similar manner with the investment ring lying on the wire netting over the Bunsen burner. The use of a thermometer, as previously described, is necessary. A temperature of 900°F. should be maintained for about 15 minutes, when the heat is gradually increased until a dull red, 1300°F. is visible through the sprue hole. At this point the casting should be made. If a muffle with thermostatic control is used, casting may be done at a temperature anywhere between 1100 and 1600°F., since the investment reaches its maximum expansion at these temperatures.

Casting the Inlay.—The mold having been expanded, the temperature to which it has been heated should be as nearly maintained as possible until the gold is melted, cast into it and has solidified. If the investment were allowed to cool before casting, it would shrink and the expansion produced by heating would be lost. In addition, its crushing strength would be greatly reduced, with the possibility of bruising the walls of the pattern chamber and producing a rough or imperfect casting. Consequently, all preparations for casting, such as preparing and cleansing the gold, lighting the blow pipe, adjusting the casting machine, etc. should be made before removing the inlay ring from the oven. As soon as all of these details are accomplished, the gold should be melted and cast into the mold as quickly as possible.

Numerous types of casting machines are available. These appliances act on three different principles; (1) those which force the gold into the mold by pressure of air, nitrous oxide gas, or steam; (2) those which revolve and force the gold in by centrifugal force; and (3) those which draw the gold in by forming a vacuum in the pattern chamber. Casting golds, on being heated, pass through five visible stages: (1) they congeal into a button; (2) they turn cherry red; (3) they become spheroidal in shape; (4) they become light yellow and mirror like on the surface and quiver under the blow-pipe; (5) they approach white heat; (6) they reach white heat, boil and spray fine particles from the mass. For casting, they should be heated until they are well into the fourth stage, when the mirror like surface is readily apparent and quivering is easily visible. Then the cast should be made and pressure maintained until the gold is solidified. The casting pressure varies with the different types of machines and averages from 6 to 8 or 10 pounds. Excessive pressure should be avoided, because it is not necessary and may damage the pattern chamber. Overheating of the gold is likely to burn out the lower fusing metals in the alloy, produce segregation of the heavier metals to the bottom of the casting and tends to produce a rough casting. The blow-pipe should be adjusted to the brush or reducing flame, to avoid oxidation and the formation of voids in the casting from metallic oxids. For this reason, the finely pointed oxidizing flame, as used in soldering operations, should not be used. With properly adjusted flame directed steadily upon the gold, the proper fluidity should result in about one and a half minutes. Usually from 4 to 6 pennyweights of gold are required. A sufficient amount should be used to duplicate the pattern and sprue and to leave a button in the crucible of the investment ring as large, or larger, than the inlay. After the inlay is cast, allow the ring and investment to cool to room temperature before removing the casting. Now carefully remove the casting from the investment with a small knife blade, being careful not to damage fine margins, and scrub off the investment clinging to the casting with a stiff brush. Then pickle the inlay with its attached gold stem and button

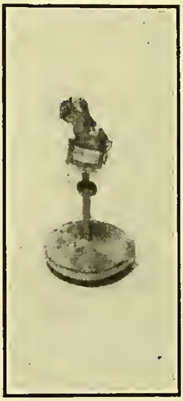


FIG. 676.—Gold inlay with sprue and button attached, after removal from investment.

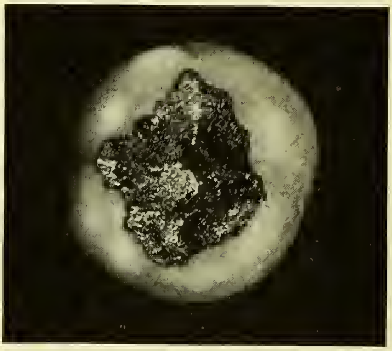


FIG. 677.—Gold inlay for occlusal surface of a molar, fitted into the cavity before polishing.

by placing in an acid ladle and boiling in 50% solution of sulphuric acid. Allow it to cool slowly after pickling, to avoid annealing or softening. After washing thoroughly in water, examine it carefully for the presence of any small nodules on its cavity surface, which would interfere with its proper seating. If found, remove them with a small stone, after which it is ready for fitting and polishing. Fig. 676.

Finishing, Polishing and Cementing.—In simple inlays, the gold sprue and button may now be cut off close to the surface to which it is attached. In other cases, particularly mesio-occluso-distal and mesio-inciso-distal inlays, it will often be an advantage to leave the sprue on for a while, since it offers a convenient hold on the inlay during the finishing down of the gold, after which it should be removed. The temporary filling previously placed in the cavity should now be removed and the inlay placed in position. As a rule, a little pressure or a few gentle taps of the mallet should seat it. If not, it should be removed and search made for the possible presence of nodules on its cavity surface, which, if found, should be trimmed off. As soon as seated to place, examine it carefully for fit at the margins, contour, anatomical form and contact point. The gingival margin should be given a specially careful examination to see that it is covered and that the inlay fits perfectly at that point. If there are imperfections in the fit to the cavity, the casting should be discarded and a new one made. Owing to the large number of details incident to inlay construction, failures will necessarily occur. In these cases, if the operator is honest, he will unhesitatingly discard the work, intelligently explain the matter to the patient, and proceed to construct a restoration which will be a credit to his professional reputation, and which will afford the service which the patient naturally expects when his welfare and health are at stake. Fig. 677.

During the removal of the wax pattern, the contact point was flattened and proper "knuckling" with the adjacent tooth was destroyed. It is now necessary to restore the contact to its proper form and location. To do this, the inlay is covered with an anti-flux, such as a solution of prepared chalk or whiting in water, except that portion where the contact is to be restored. Now, a sufficient amount of 18 or 20 carat solder is flamed on to the surface at the proper point to restore contact with the proximating tooth. This is readily accomplished by holding the inlay with a pair of soldering pliers in the flame of a Bunsen burner and melting the solder to place. The casting should now be tried in the cavity again and the contact tested and measured with floss silk. If not full enough, additional solder should be added and the inlay again pickled and tried in place. A final test of the contact should be made after the inlay is polished and before cementing to place.

Now place the inlay in the cavity and burnish the margins closely to the cavo-surface angle. Then remove it and finish and polish all of it, except the margins, out of the mouth. Now place the inlay in the cavity again and polish the entire surface including the margins. Also burnish the margins again at this time. The same instruments used for polishing gold fillings, such as stones, files, finishing burs, strips and disks should be used. Special attention should be given the gingival margin, and care should be used not to flatten the contact point previously soldered on. Figs. 678 and 679.

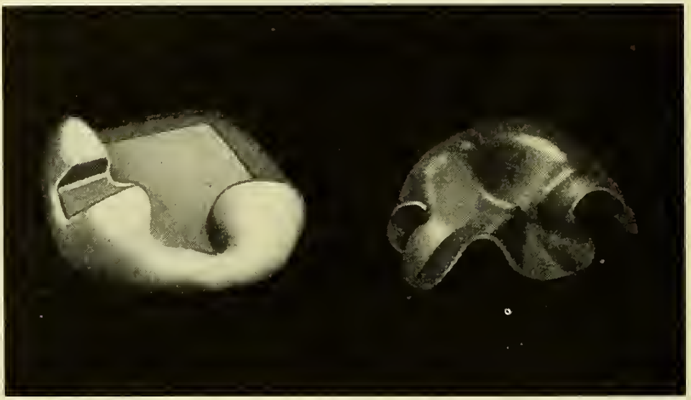


FIG. 678.—Cast inlay, polished and ready to cement into an extensive cavity in a molar.

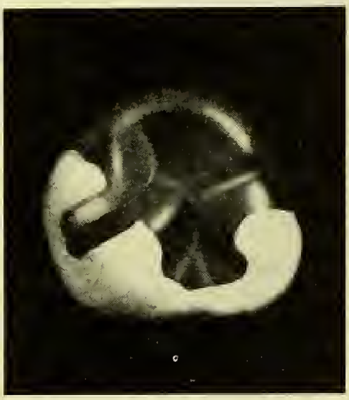


FIG. 679.—Completed inlay.

The inlay is now ready for cementing into place. It should be realized that the cement is to be used only as a sealing agent for the

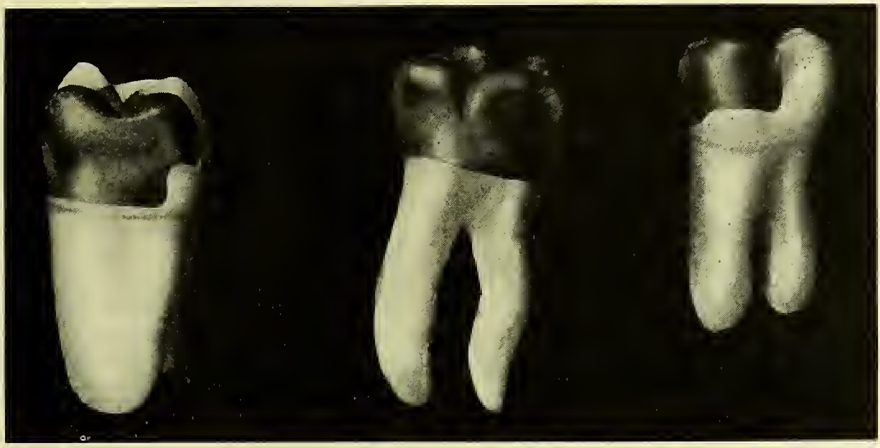


FIG. 680.—Gold inlays.

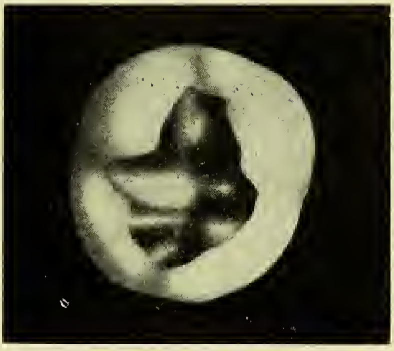


FIG. 681.—Gold inlay.

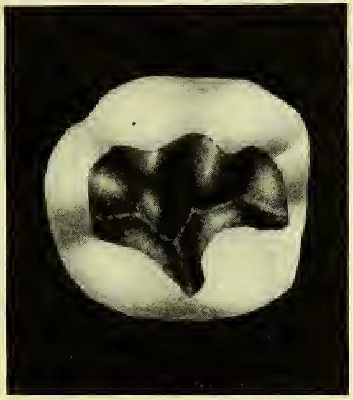


FIG. 682.—Gold inlay.

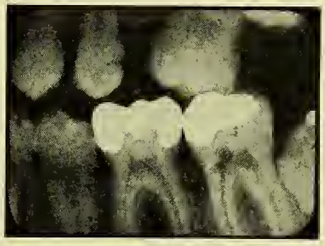


FIG. 683.—Good inlay on first molar.

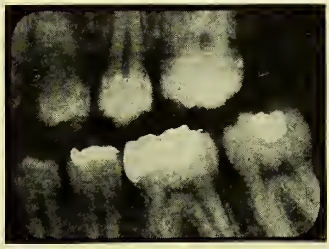


FIG. 684.—Inlay, lower first molar, improperly contoured.

joint between the inlay and the cavity wall and not for retention. This stresses the importance of proper retention for the cavity. The more perfectly the inlay fits the cavity, the smaller will be the cement line and the less the tendency to its dissolution. If the cavity margins are properly formed and the inlay perfectly fits them, the cement line is concealed from view. However, it still is present and this is one of the shortcomings of the inlay which cannot be overcome, it matters not how perfectly it is constructed. Figs. 681, 682 and 683.

For cementing, the cavity must be perfectly dry, either through application of the rubber dam or through the use of absorbents, and moisture must be excluded until the cement has set. Everything being in readiness, the cement is mixed to a thick creamy consistency, all cavity walls and margins and the entire cavity side of the inlay first covered with cement and then the piece is carried to place. Now maintain pressure on the inlay for several minutes until the cement has become fairly hard. Then the excess of cement should be removed and a final polish given the inlay with strips, disks and other polishing materials, as used for gold fillings. The bite should be thoroughly tested for occlusion and contact, and relieved, if necessary, to prevent occlusal trauma, when the patient may be dismissed. It will be well to see the patient again in a few days to check up the work. Figs. 683 and 684.

THE INDIRECT METHOD

The method of making inlays previously described is known as the direct method, because the wax pattern is constructed directly into the prepared cavity in the mouth of the patient. The chief disadvantages in this method are the time consumed at the chair and the difficulty of obtaining a correct wax pattern in locations of difficult access, obscured from view by saliva. In these cases, the indirect method, in which the wax pattern is made out of the mouth, may be used to advantage, thus saving the time of both patient and operator at the chair and often producing surer results. The principal disadvantage in this method is in the use of a larger number of impression and model materials which are capable of changing form, with the consequent added danger of producing distortion with them, unless great care is used in their manipulation. In discussing the direct method, procedures were described for correlating the variables existing in the materials used. In the indirect method, now to be described, two additional materials, namely modeling compound for taking the impressions and amalgam for making the die, both of which are subject to volume changes under temperature, and setting or hardening influences, are used, which further complicate the problem. Until the expansion ratios of these are correlated with those of the other materials, the indirect method will still be on an empiric basis. In view of the space devoted to a discussion of the direct method, a brief description of the indirect method will suffice.

Technique of the Indirect Method.—Prepare a matrix for taking an impression, by trimming a copper band to loosely fit the tooth. In mesio-occlusal cavities, the gingival part of the band must be trimmed away at its distal portion, as it will not enter past the contact point of the proximating tooth unless that is absent. In disto-occlusal cavities the band will be trimmed away from its mesial portion for similar reasons. In M. I. D. cavities, this will often not be necessary. In bell crowned teeth, the gingival portion of the buccal and lingual parts of the band must be taken away, else the modeling compound impression, which is to be taken of the prepared cavity and tooth, will not draw over the rounded buccal and lingual surfaces without distortion. The band should fit well down over the gingival margin of the cavity, but should be so trimmed and shaped as not to damage the gingival tissues. After fitting the band, it is filled with softened modeling composition, carried to place and an impression of the cavity and tooth is carefully obtained. After thoroughly chilling it, the band containing the impression is removed from the mouth in a manner to prevent distortion. Fig. 685. The compound impression should be carefully trimmed with a sharp thin-bladed knife

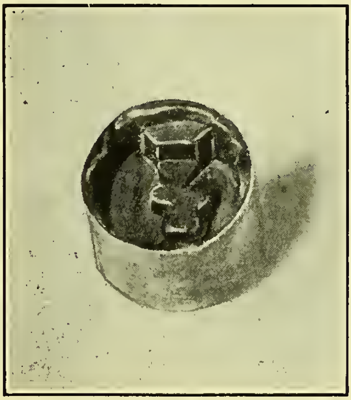


Fig. 685.—Copper band containing modeling compound impression of a cavity prepared for a gold inlay.

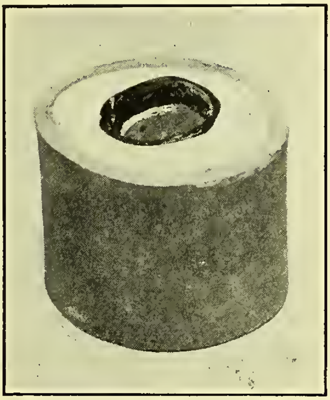


Fig. 686.—Copper band wrapped with boxing wax and invested in plaster, surrounded by rubber ring.

to remove any excess which has been forced out at the gingival margin. Now, a thin piece of casting or boxing wax, 28 to 30 gauge, should be wrapped closely around the impression and band matrix and extended about 3/8 of an inch beyond and along the gingival margins of the band and its contained impression. Imbed this boxed impression, with the open end showing the cavity facing up, in a mix of plaster which has been previously placed in a small rubber ring to hold it steady and prevent its spreading during setting. In mixing the plaster, accelerators should not be used. Fig. 686.

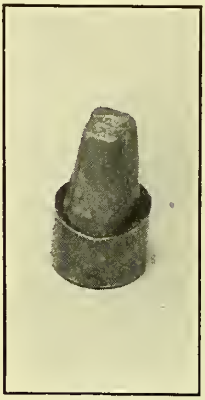


FIG. 687.—Amalgam die, still in copper band containing the modeling compound impression, removed from the plaster investment and rubber ring.

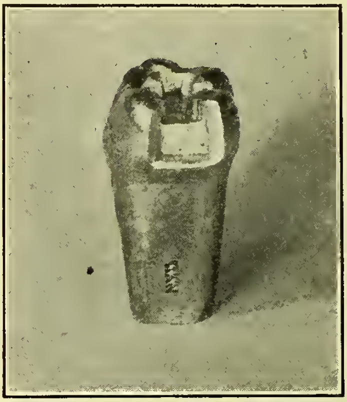


FIG. 688.—Amalgam die completed.

Now, after the plaster base has hardened, mix into a plastic mass a sufficient amount of a good silver-tin amalgam; or Tech-alloy may be used. The mix should be fairly soft, to allow sufficient time for packing. Pack the amalgam as in making a good filling, into the impression of the cavity and tooth and up to the edge of the boxing wax previously adapted. After it has thoroughly set, remove the rubber ring and plaster from around the amalgam die, immerse the die in warm water and remove the softened compound and wax. Fig. 687. In this way a duplicate of the cavity is provided on one end of the amalgam die. Then trim the die from the cavity margins to its opposite end and taper it so that it simulates the shape of a tooth root. For this purpose a stone in the engine, or a file is used, followed by engine disks to perfect the tapir and to smooth it so that it may later be readily removed from the plaster cast, now to be made. Fig. 688.

A wax or compound impression and bite is taken of the tooth and those adjoining and articulating with it, at the same sitting at which the previously described impression of the cavity is made. On completion of the die, this is now placed in position in the cavity in the impression and bite, when casts are then poured and mounted on the articulator. On removal of the wax or compound bite-impression, the amalgam die will be in proper position and relationship on the articulated cast.

After lubricating the cavity in the amalgam die with cocoanut oil, the wax pattern is constructed on the die in the same manner as described for making it in the mouth in the direct method. Fig. 689. Following this, the remaining procedures for making the inlay are the same as previously described. After casting, the inlay is then fitted into the cavity in the amalgam die, its occlusion tested on the articulated casts and much of the finishing and polishing completed on the die. During these procedures, if a proper tapir has been given the "root" of the die, it may be removed from the cast to facilitate more ready finishing and polishing of the inlay. Also, it may easily be replaced to test the occlusion. After fitting the inlay to the die, it should be pickled, to remove traces of amalgam which may contaminate it. If the inlay does not fit the die, it cannot be swaged to it, as claimed by some, since the amalgam is softer than the inlay. In attempting to do this, what actually occurs is the swaging of the die to the inlay, which will not remedy matters. On completion of the inlay, it is tried in the mouth and minor defects corrected, cemented to place, again polished if necessary, the occlusion tested and the patient dismissed.

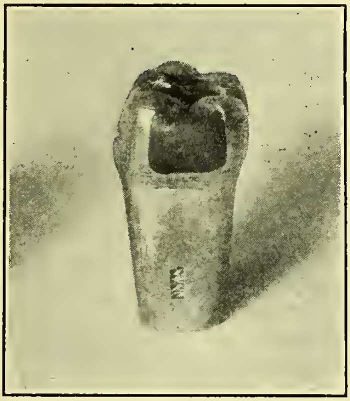


FIG. 689.—Wax model constructed on amalgam die.

THE DIRECT-INDIRECT METHOD

This is a combination of both methods. In very difficult cases, the wax pattern may first be partially completed in the mouth. Following this, an impression, bite and amalgam die are obtained and articulated, as described in the indirect method. The wax pattern is then completed on the amalgam die, when, if desired, it may be again tried in the mouth and tested for proper fit. After this, the procedures are the same as in the direct method.

Bibliography

1. Van Horn, C. S.: Eliminating variables in the making of cast gold inlays, Dental Cosmos. vol. LXVII, 1925, p. 159.
2. Tinker, E. T.: Gold inlays, Jour. Amer. Dent. Assoc., vol. XIII, 1926, p. 317.
3. Thompson, Emery C.: Manipulation of wax, investments and casting golds, Jour. Amer. Dent. Assoc., vol. XI, no. 2, Feb. 1924, p. 203.
4. Volland, R. H.: Wax pattern and casting, Jour. Amer. Dent. Assoc., vol. XIV, no. 11, Nov. 1927, p. 1988.
4. Volland, R. H.: Low heat elimination, Jour. Amer. Dent. Assoc., vol. XV, no. 8, Aug. 1928, p. 1545.
5. Hollenbeck, Geo. M.: Practical contribution to standardization of the casting technic Jour. Amer. Dent. Assoc., vol. XV, no. 10, Oct. 1928, p. 1917.
6. Grunn, Albert P.: High heat method of wax elimination, Jour. Amer. Dent. Assoc. vol. XV, no. 8, Aug. 1928, p. 1535.
7. Maves, Herman A.: Controlling variables in the casting process, Jour. Amer. Dent. Assoc., vol. XV, no. 8, Aug. 1928, p. 1550.
7. Maves, Herman A.: Methods for controlling variables in the casting process, Jour. Dental Research, vol. VIII, no. 2, April 1928, p. 151.
8. Meyer, F. S.: Explanation of and partial remedies for failures in cast inlays, Dental Cosmos, vol. 68, 1926.
8. Meyer, F. S.: Cast gold inlays. Some sources of errors and their correction, Jour. Amer. Dent. Assoc., vol. XVI, 1929, p. 812.

Colemen, R. L.: Physical properties of dental materials, Progress report of research on dental casting process, Dental Cosmos, vol. LXVIII, 1926, p. 743.

Bureau of Standards Research Paper no. 32, Dec. 1928.

Bureau of Standards: Cast materials; methods of using, values, compositions, Dental Cosmos, vol. LXVIII, Aug. 1926, p. 743.

Bureau of Standards: Selection of materials, casting to dimensions, need for testing, Jour. Amer. Dent. Assoc., vol. XIV, Feb. 1927, p. 189.

Bureau of Standards: Casting materials; physical properties, methods of testing, Dental Cosmos, vol. LXIX, Oct. 1927, p. 1007.

Bureau of Standards: Analysis of dental gold alloys, Scientific Paper, no. 532.

Bureau of Standards: Dental gold alloys; tentative specification and test methods, Jour. Amer. Dent. Assoc., vol. XV, April 1928, p. 627.

Coy, Herbert D.: Jour. Iowa Dental Soc., May 1932.

Taylor, Paffenbarger and Sweeney: Dental inlay casting investment, Jr. A.D.A., Dec. 1930, p. 2266; specification for inlay wax, Jr. A.D.A., Jan., 1931, p. 40; inlay casting gold, Jr. A.D.A., Jan. 1932, p. 36.

Volland and Paffenbarger: Cast gold inlay technic, Jr. A.D.A., Feb. 1932, p. 185.

CHAPTER XXII

CERAMICS—THE PORCELAIN INLAY—CONSTRUCTING THE MATRIX—COMPOSITION AND CHARACTERISTICS OF PORCELAIN

The word "ceramics" is derived from the Greek, *keramos*, potter's earth or earthenware, and literally means the art of pottery. Ceramic art comprises all art objects made of baked clay, such as vases, urns, cups, statuettes, etc., and includes all varieties of artistic earthen-ware and porcelain. Those kinds of pottery or ceramic ware which have a translucent or semi-translucent body with superior whiteness or hardness, and which are fusible at very high temperature, are spoken of as porcelain, or china, or china-ware. The word "porcelain" originates from the French *porcelaine* or the Italian *porcellano*, originally the *Cyprea porcellano*, a cowrie or porcelain shell, the beautiful polished surface of which resembles porcelain ware and from which it was thought by some to be made. The Italian word is supposed to be derived from *porcella*, which is the diminutive of *porco*, pig, on account of the attributed resemblance of the shell to a pig's neck, or to the genital organs of a female pig.

HISTORICAL

A fine, translucent kind of earthen-ware was first made in China and Japan over one thousand years ago. After hundreds of years, the French, Italians and Dutch produced a type of faience or clay, opaque pottery, which was covered with enamel. The first fired mixture of vitrified porcelain to be made in Europe is attributed to Boettcher in 1709. In 1759 Josiah Wedgewood of England introduced a type of semi-vitreous pottery which he called "Queen's ware." This was the predecessor of the well known Wedgewood pottery of the present day. In the latter part of the 18th century, the French were manufacturing frit porcelains, made by fusing kaolin and ground quartz together with a fusible glass or frit. Increased knowledge of the ceramic art gradually developed in Europe, two types of porcelain being evolved, viz. the "hard porcelain" of continental Europe and the "bone china" of England.

Artificial porcelain teeth of crude type were first introduced into France in 1815. Improvements in their manufacture and type are largely due to the work of Americans. The early advances in this field were prosecuted by such men as Chas. W. Peale, Samuel W. Stockton, James Alcock, Elias Wildeman and Samuel S. White. In 1844 White began the manufacture of porcelain teeth on a commercial basis, since which time they have been gradually brought to their present state of development. Doctor John Allen, an American Dentist, presented the first continuous gum denture, a further development of the ceramic art in dentistry in 1846, and which he patented in 1851. This was followed in 1857 by the presentation of a crude enamel inlay filling by A. J. Volk.

Early Methods.—Porcelain inlays, ground and fitted from sections of porcelain teeth were described by B. Wood in 1862. Sections of porcelain and glass rods were also ground and cemented into place for the same purpose. In 1889 W. Herbst of Bremen introduced a system of making inlays from ground powdered glass fused in a matrix of platinum-gold foil. The ground glass in several colors was made from Venetian glass beads. Previous to this, in 1837 John Murphy of London had introduced a platinum-foil technic which made possible the present day development of the method of porcelain inlay construction. In 1880 Doctor William Rollins of Boston described a method for burnishing a metallic matrix into the cavity, which is the predecessor of our present methods.

The first all-porcelain jacket crown was patented by C. H. Land in 1889 He also invented in 1884 a gas furnace for fusing porcelain. Previous to this time, crude coke furnaces were the only reliance. This was soon followed by the smaller and better furnace of Downie and in 1894 by the first electric furnace of L. E. Custer. In 1895 W. E. Christensen described a process for making molded and fired porcelain inlays, and this was followed by the introduction of the high fusing bodies of Close and Downie. N. S. Jenkins of Dresden presented in 1898 the first low-fusing porcelain for making inlays. There soon arose a demand for better and higher fusing porcelain and this need was met by the commercial introduction in 1899 by Ash and Son of London, and a short time later by the S. S. White Company and other concerns, of improvements in high fusing bodies. There have been continuous developments in these from then up to the present time. With the introduction of mineral stains in 1904, it is now possible for the operator to produce porcelain inlays and jacket crowns which may be considered among the highest types of the ceramic art.

Fused porcelain is now considered to be of great value in the construction of the inlay and jacket crown, as well as of certain types of bridgework, and probably will continue so for a long time. The difficulty of obtaining proper shades, as well as the time and great skill required in manipulation are the principal drawbacks to its use. In addition to those already mentioned the names of Doctors D. O M. LeCron, E. B. Spalding, John Q. Byram and Albert Leland LeGro may be mentioned as prominent among the more recent pioneers in the development and perfection of porcelain work in dentistry. From the standpoint of esthetics there is no material which can compare with it in reproducing beauty of form and harmonious blend of shade and color in the restoration of lost tooth structure. Since the failure of the silicate filling, a revival of interest is being manifested in its use, and additional enthusiasts are slowly being added to the ranks of the still small body of dentists, scattered here and there in this country and abroad, who are willing or able to develop the necessary type of skill and artistic ability to proficiently manipulate it. "It takes a master to truly represent nature."

THE PORCELAIN INLAY

Steps in Porcelain Inlay Construction.—The stages in the construction of the porcelain inlay consist in (1) preparation of the cavity for its reception; (2) making a platinum matrix which perfectly fits the cavity; (3) fusing porcelain into the matrix to restore the form of the tooth; (4) removal of the matrix from the porcelain and (5) polishing and cementation of the inlay into the cavity.

Advantages and Disadvantages.—The chief *advantages* in the porcelain inlay are its harmonious color, its low conductivity and the tolerance of the soft tissues to its presence, when placed in close proximity to them. Another advantage mentioned for it by porcelain enthusiasts is that its highly glazed surface seems to repel the formation and localization of bacterial plaques. When the various shades are properly selected, blended and manipulated, a perfect reproduction of the natural tooth shades may be accomplished and the resulting restoration is obscured from view. If "the highest function of art is to conceal art," then the properly trained worker has at his disposal this ideal material to perform that function. Its conductivity is, with the exception of guttapercha, the lowest of the restorative materials. One of the chief *disadvantages* in the porcelain inlay is its low crushing resistance in thin sections and when built out to thin edges, owing to its brittleness. Other disadvantages are its great difficulty of manipulation, the necessity for the cement line, present in all inlay construction, its lack of perfect adaptation to cavity walls, with consequent absence of the grip on it, of elastic dentin, as seen in gold fillings, and the impossibility of excluding the saliva and of preserving freshly cut cavity walls during its construction.

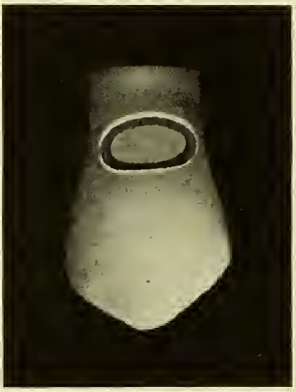


FIG. 690.—Gingival third cavity prepared for porcelain inlay.

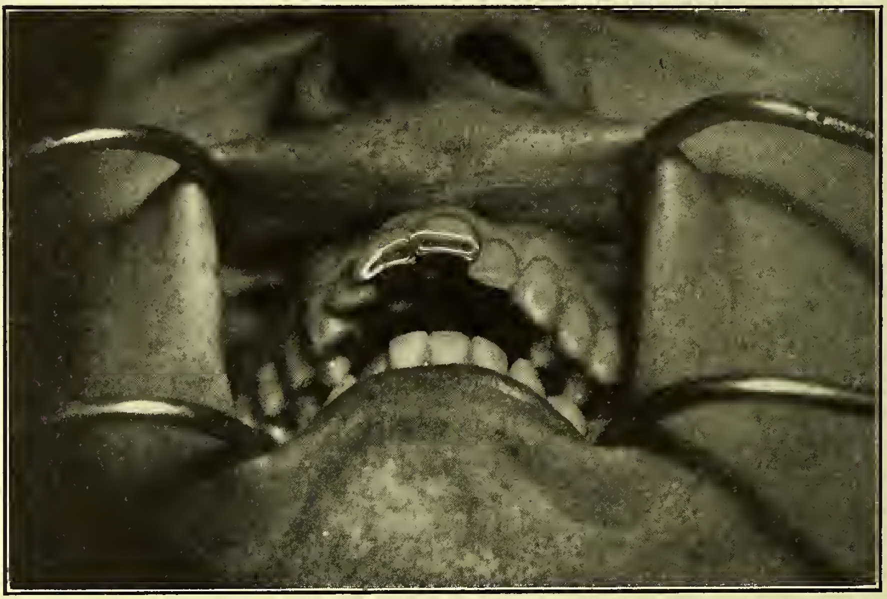


FIG. 691.—Cavities prepared on the incisal surfaces, holes drilled for the reception of pins for the restoration of the incisal tips of the central incisors with porcelain.

Indications for Use.—The porcelain inlay in the hands of the average dentist has a rather limited range of usefulness. It cannot be applied to surfaces which are subjected to moderate or high masticating stress, owing to its brittleness. Consequently, in the majority of cases, it should usually be confined to gingival third cavities exposed to view and where esthetics are the chief consideration (Fig. 690); to eroded

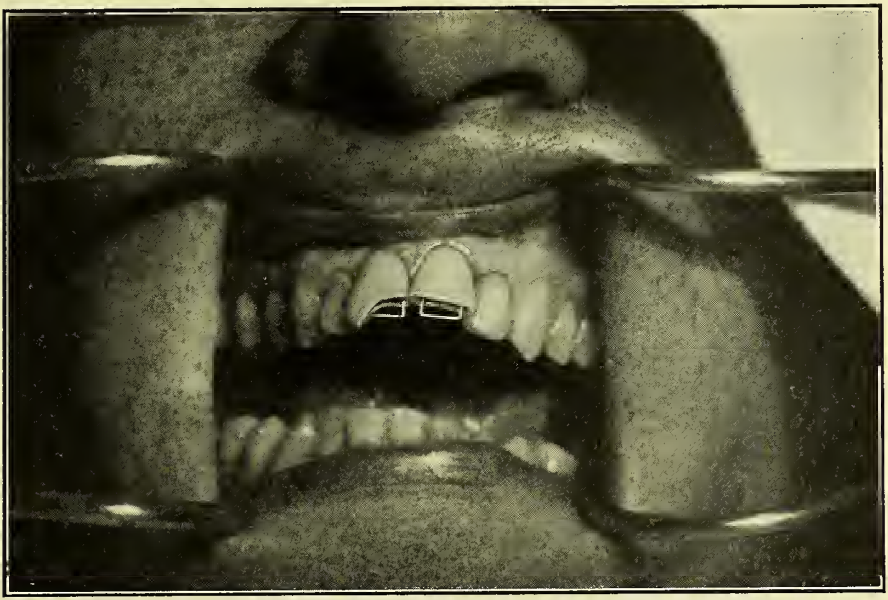


FIG. 692.—The cavities shown in Fig. 691 with the pins in position.

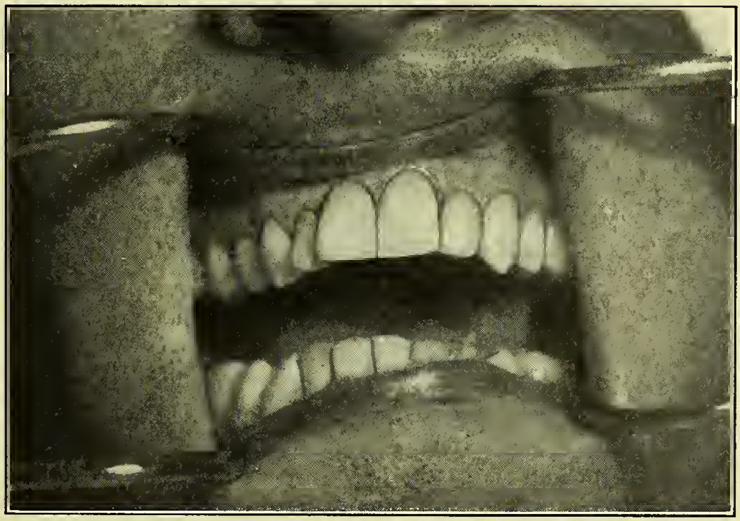


FIG. 693.—Teeth shown in Figs. 691 and 692 restored with porcelain inlays.

areas in the same location; and to hypoplastic anterior teeth presenting pits or grooves of a disfiguring character. Cavities of large size in the proximal surface of the anterior teeth prohibiting the display of gold are ideal cases for porcelain inlays, provided the skill of the operator has been developed sufficiently to intelligently cope with the difficulties incident to shade selection and proper manipulation of the material. In smaller Class III cavities, gold fillings, when properly protected from view, should be selected. Some cases of incisors with fractured incisal edges resulting from a fall or blow may often be effectually restored, the entire incisal portion being reproduced with a porcelain inlay. However, if the fracture is of considerable extent and encroaching closely

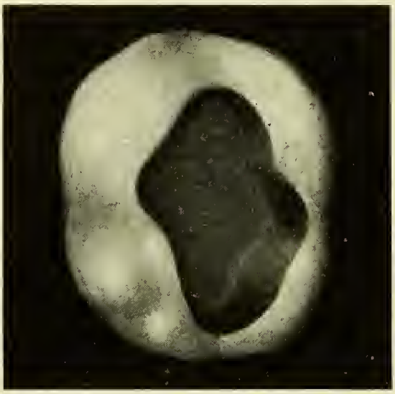


FIG. 694.—Extensive cavity on the occlusal surface of a molar, prepared for a porcelain inlay.

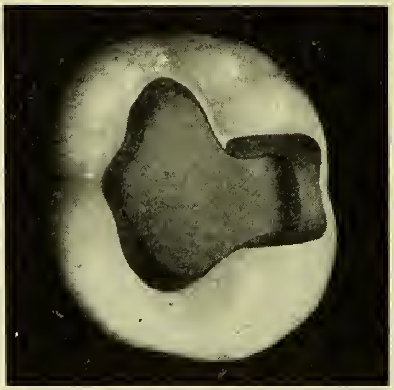


FIG. 695.—Extensive occlusal cavity involving the buccal groove prepared for a porcelain inlay. Step form.

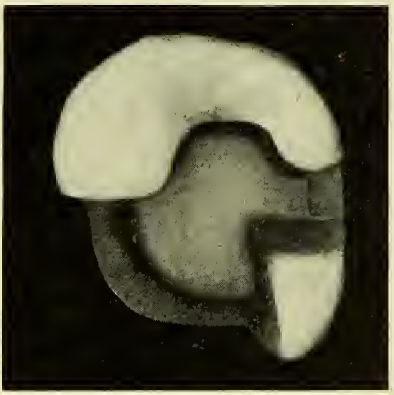


FIG. 696.—Extensive preparation for a porcelain inlay on a molar.

over the pulp, a porcelain jacket will frequently be indicated. Figs. 691, 692 and 693.

The porcelain inlay is usually not indicated in Class I, II and IV cavities or on abraded surfaces, on account of its friability and the tendency to fracture at its margins under stress. However, skilled porcelain operators often apply it to proximo-occlusal and proximo-incisal cavities, and even to badly abraded or broken posterior teeth, where the stress of mastication is low, or where esthetics are paramount. However, in cases of this nature, the danger of fracture is an ever present menace and one which should prohibit its use, certainly in the hands of the inexperienced. Figs. 694, 695 and 696.

CAVITY PREPARATION

Cavity preparation for the porcelain inlay requires very slight modifications of the types shown and described in the chapters on "Gold Inlays." The principal features of the cavities designed for the reception of this material are as follows, viz.:

In proximal cavities, adequate access is a necessity, either by cutting or separation, or both, to allow for withdrawal of the matrix or the impression material. The outline form should not follow a developmental groove, or cross a ridge at its highest point. Owing to the friability of the material, margins should be extended to points least susceptible to crushing stress. The outline form should never be circular, else difficulty may be experienced in seating the inlay into its proper position, after fusing. In cases of this nature, a small depression may be sunk into the floor of the cavity at some point with a number 1 round bur, to serve as a guide in the proper seating of the finished inlay. Adequate resistance form is a necessity, and maximum retention form is required in all cases subjected to stress. All line and point angles should be sharp and well defined, as for the gold inlay. Surrounding walls should meet the basal wall or seat at a slightly obtuse angle, to admit the ready withdrawal of the matrix. However, the more nearly parallel these walls are, the greater the retention. In Class III and V cavities the axial wall should be convex rather than flat, to avoid encroachment on the pulp and to, at the same time, afford greater depth to the cavity and bulk of porcelain in the region of the lateral boundaries. Figs. 697, 698, and 699. Retention may be increased by pins, more generous step forms than for gold, double steps, extension of porcelain into pulp chambers, and similar measures. The cavity should be so prepared as to give sufficient bulk to the material, to resist stress. The cavo-surface angle should be a right angle, or if a bevel angle exists, it should be deeply buried to afford strength to the porcelain. The cavity should be washed, first with chloroform to dissolve mucous and fatty matters, then with alcohol, and thoroughly dried before setting the inlay. The instruments used in the preparation of the various types of cavity are the same as those previously described in the chapters on cavity preparation for the gold filling and gold inlay. In addition to these, some operators use for preparation of the box shape cavities with their flat parallel or slightly diverging walls, tapered fissure burs, cross cut and plain, special inlay burs, fine finishing burs, straight and tapered,

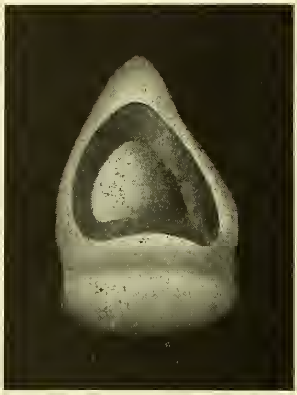


FIG. 697.—Class III cavity preparation, showing convex axial wall.

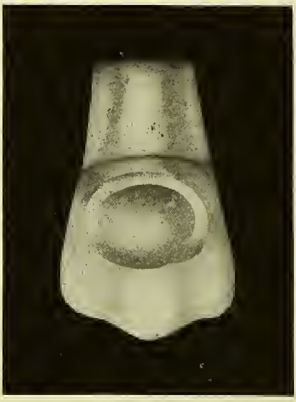


FIG. 698.—Class V preparation showing convex axial wall.

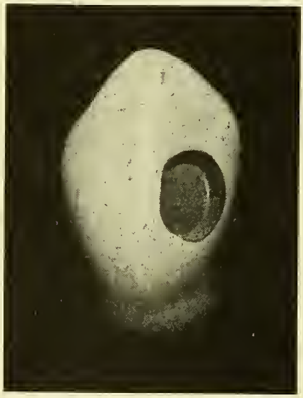


FIG. 699.—Cavity in a hypoplastic pit on the labial surface of a cuspid prepared for a porcelain inlay.

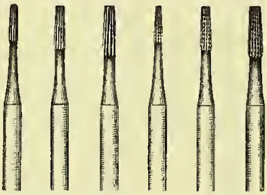


FIG. 700.—Tapered fissure burs, plain and dentate. Nos. 600, 601, 602, 603, 604, and 605.

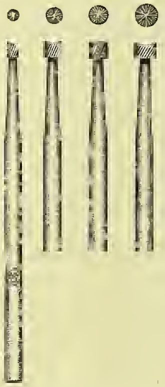


FIG. 701.—Inlay burs, Nos. 1, 2, 3 and 4.

Chayes Crystallon stones and Arkansas stones, as illustrated in Figs. 700 and 701. For polishing the enamel walls, the fine cut finishing burs may often be used to advantage.

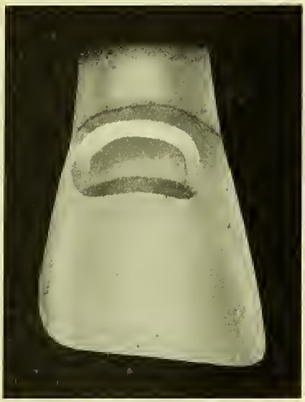


Fig. 702.—Class V cavity in a central incisor.

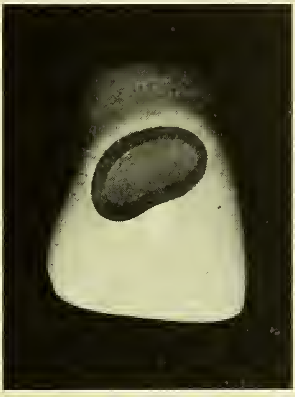


Fig. 703.—Large labial cavity on a central incisor.

In **Class V Cavities** the form and technic of preparation is similar to that for the gold inlay and no special description is necessary. Figs. 702, 703 and 704. In **Class III Cavities** the approach may be made either from the labial or lingual aspect. Adequate separation is essential, to allow for ready withdrawal of the matrix, if the direct method is used. In fact, more room is often required for withdrawal of the matrix than that required for removal of the wax pattern in gold inlay construction. There is no objection to extension of labial walls since, with porcelain,

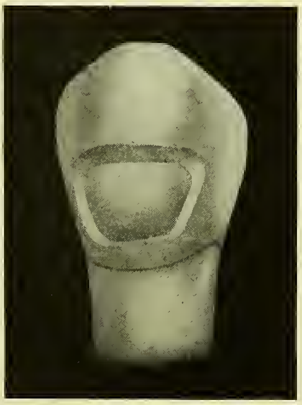


Fig. 704.—Large buccal cavity on a lower bicuspid.

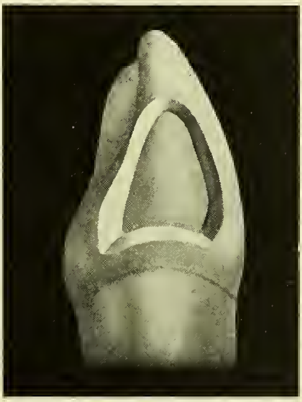


Fig. 705.—Class III cavity for porcelain on a central incisor.

the esthetic requirements are readily met. The direction of approach will depend on the strength of the labial and lingual walls, bearing in mind that the inlay must be seated against either a strong labial or lingual wall to resist stress. Figs. 705, 706 and 707.

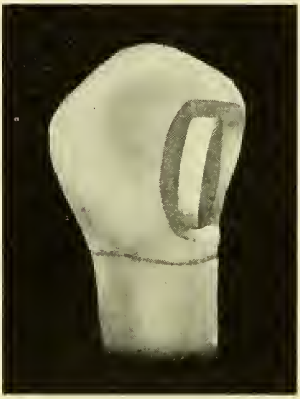


Fig. 706.—Class III cavity (with lingual "draw") on a cuspid.

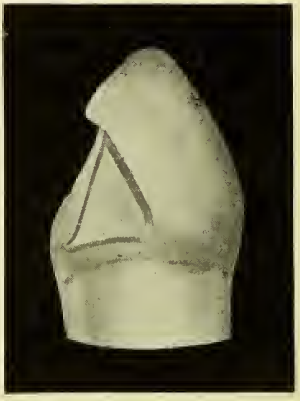


Fig. 707.—Same cavity as shown in Fig. 706.

In **Class II Cavities** provision must be made for as much bulk of porcelain as conditions will admit. In the occlusal part of the cavity, care must be taken to extend buccal and lingual margins well out of the area of stress, if they approach the points of the cusps, else the porcelain will not have sufficient bulk to resist the forces of occlusion. This will sometimes involve extensive removal of cuspal elements, and

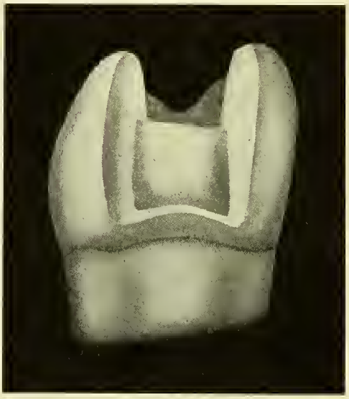


Fig. 708.—Class II cavity prepared for porcelain inlay.

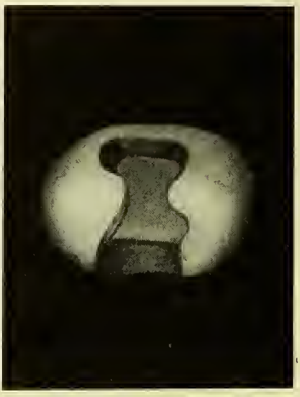


Fig. 709.—Class II cavity on a bicuspid. Occlusal view.

carry the cavity well over on to buccal and lingual surfaces. Figs. 708 to 712.

In **Class IV Cavities** rather extensive cutting is often necessary to secure sufficient bulk and strength of porcelain. Extension of the cavity well over to the lingual and labial surfaces, wide cutting of the step portion, and the use of double steps, or multi-steps to secure bulk of material is occasionally indicated. Figs. 713, 714 and 715. Even under these circumstances, the margins of the inlay are often subject to fracture in Class II and IV, consequently, the porcelain inlay in these cases is of very doubtful utility. Frequently it should be substituted by a jacket crown for proximo-incisal cases and by a gold filling or inlay

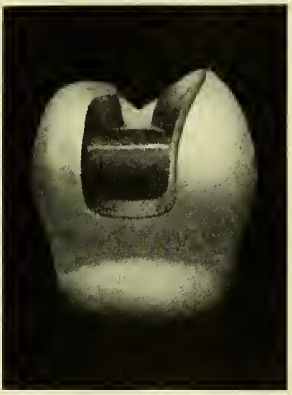


FIG. 710.—Proximo-occlusal cavity on a bicuspid.

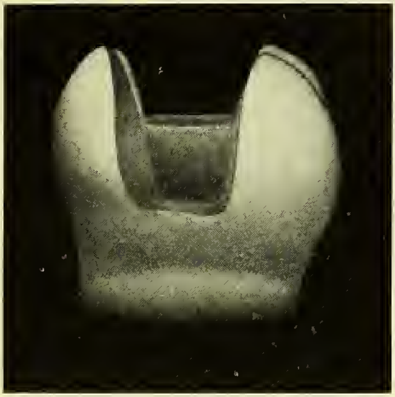


FIG. 711.—Mesio-occluso-distal cavity on a molar.

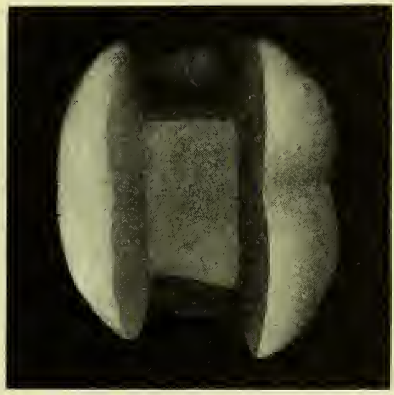


FIG. 712.—Occlusal view of cavity seen in Fig. 711.

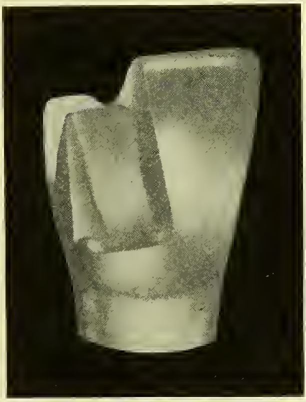


FIG. 713.—Class IV cavity in an upper central incisor. Lingual view.

for proximo-occlusal cavities. For **Restoration of Incisal Surfaces** porcelain tips may be utilized. These are sometimes indicated in cases of fracture or malformation resulting from hypoplasia. See Figs. 691, 692 and 693. These may be anchored into the dentin by means of platino-iridium pins 20–26 gauge. If conditions will admit and the pulp is not too closely involved, a cavity with a flat pulpal wall should be prepared, two holes drilled into the dentin at the mesial and distal extremities of the cavity and a staple of platino-iridium wire formed to fit into the holes. After the matrix is made, the staple is forced through it into the holes, porcelain body packed into the matrix around the staples, the matrix and staples withdrawn and the porcelain baked. In this way, the staple is attached to the matrix. In some instances, the proximity of the pulp will not permit of preparing a cavity, when the incisal portion must be ground off flat and pins inserted, to which the matrix is attached in the manner just described. Figs. 716 and 717. In the drilling of the holes, precaution must be taken not to drill into the horns of the pulp chamber. A roentgenogram should previously be taken of the tooth to serve as a guide as to the size and location of the pulp chamber. These operations are sometimes indicated in the mouths of young patients when the pulp chamber is large and near the surface. Under these circumstances care must be redoubled. The use of a **Gold Core** will often be of service to afford additional retention for the porcelain inlay or tip in those cases where a cavity cannot be drilled and the cavity or incisal portion of the tooth has to be ground flat. This is accomplished by drilling the holes as before, inserting the

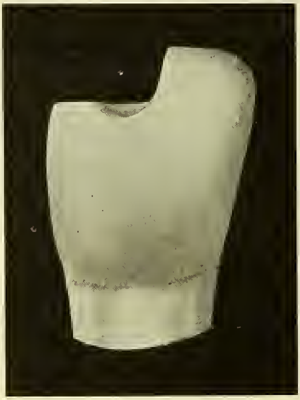


FIG. 714.—Labial view of cavity shown in Fig. 713.

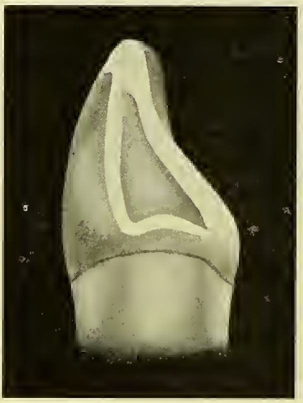


FIG. 715.—Proximal view of cavity shown in Figs. 713 and 714.

pins, usually about 20 or 22 gauge, making a wax model of the core, withdrawing the pins in the wax and duplicating the wax in gold, which is cast to the pins. The resulting gold core is cemented to place, when the porcelain tip is constructed and cemented over it, thus providing better anchorage for it. In cases where the pulp is involved, it should be removed and a pin inserted into the pulp chamber, to which the inlay is baked. In extensive cases of fractured incisal edges, it will often be

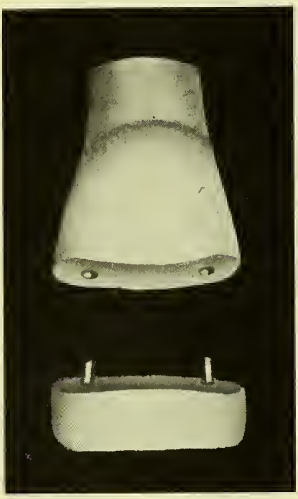


FIG. 716.—Porcelain tip with platino-iridium pins ready for cementation on a central incisor.

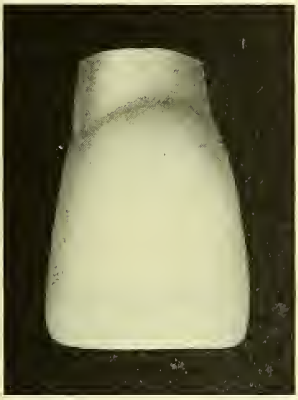


FIG. 717.—Porcelain tip shown in Fig. 716 cemented to place.

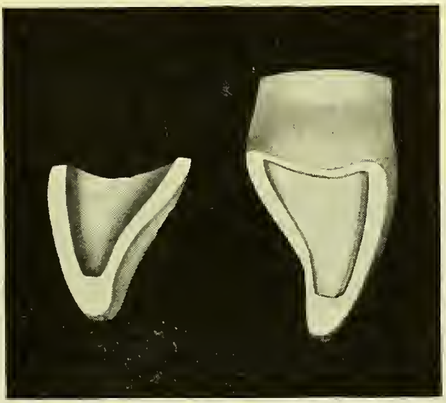


FIG. 718.—Gold core cemented to place, porcelain inlay baked and ready to be attached.

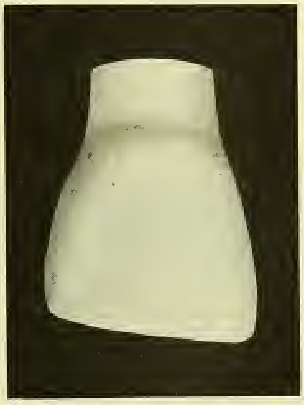


FIG. 719.—Porcelain restoration complete.

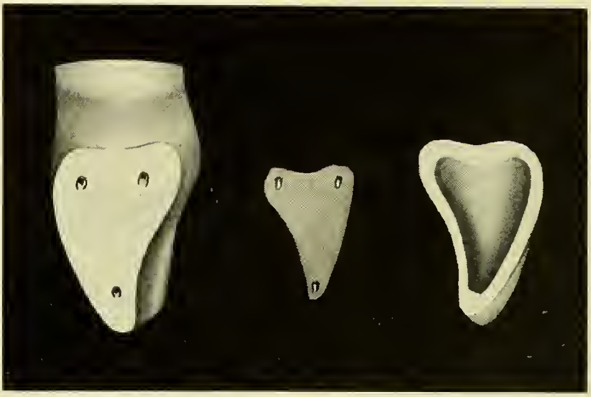


FIG. 720.—Cavity prepared, holes drilled, gold core showing pins, and porcelain inlay ready for cementation.

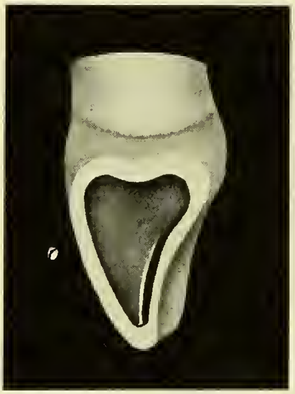


FIG. 721.—Gold core shown in Fig. 720 cemented to place.

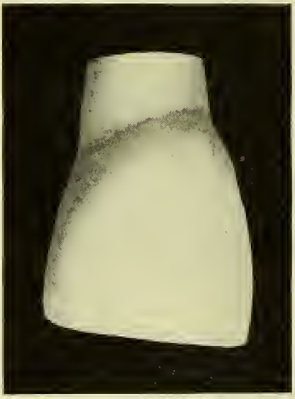


FIG. 722.—Porcelain inlay shown in Fig. 720 cemented to place.

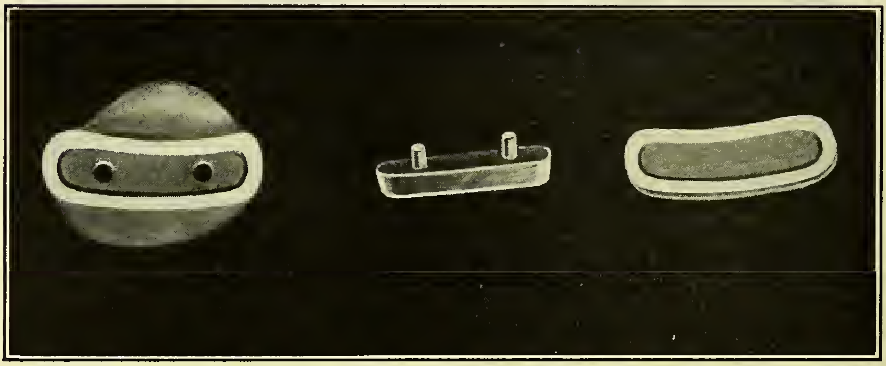


FIG. 723.—Cavity preparation, gold core and porcelain tip for restoring incisal third of an upper central incisor.

better, for reasons of strength, to cut the entire tooth down and prepare a jacket crown. In others, a partial jacket may be made to fit over the incisal third or half of the tooth. Illustrations of porcelain tips and gold cores are seen in Figs. 723 to 725.

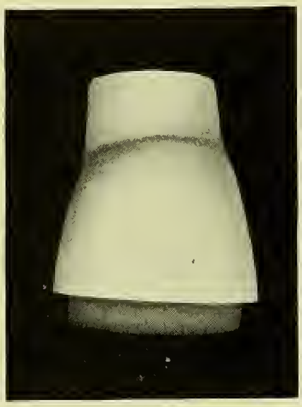


FIG. 724.—Gold core shown in Fig. 723 cemented to place.

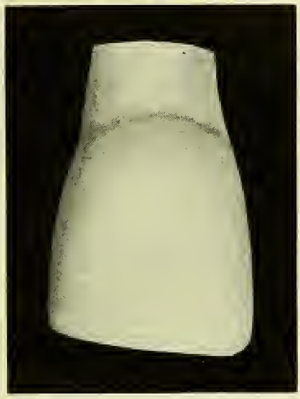


FIG. 725.—Porcelain tip complete.

MAKING THE MATRIX

Platinum foil .001 of an inch in thickness is usually preferred for making the matrix for both high-fusing, and low-fusing porcelain. Foil may be secured from the manufacturers in gauges of .001, .0015 and .002. Some operators prefer the thinner gauges. Greater care must be used in handling these, due to their thinness, to prevent distortion.

For obtaining the matrix, anneal the material in the electric furnace, carrying it to a dull yellow color at 2,500°F. and holding it at that temperature for 10 minutes.

The platinum is supplied already annealed and, in the first stages of matrix construction, annealing by the dentist may not be necessary. After working it for a while, it becomes stiff and must be annealed. The matrix is obtained by either the direct or indirect method, the direct method consisting in adapting it directly into the cavity in the mouth, while the indirect method comprises the taking of an impression, making of a die and adapting the matrix to it, when it is later tried and inserted in the mouth. Except in very simple cases, the indirect method is surer, safer and more convenient, on account of the difficulty of excluding moisture and obtaining proper access in the mouth. In the great majority of cases, the indirect method should be used. Considerably more separation is necessary in the direct method for obtaining the matrix in proximal cavities than in the indirect. The difficulty of obtaining the necessary perfection of adaptation of the matrix in the mouth should be apparent. Fig. 728.

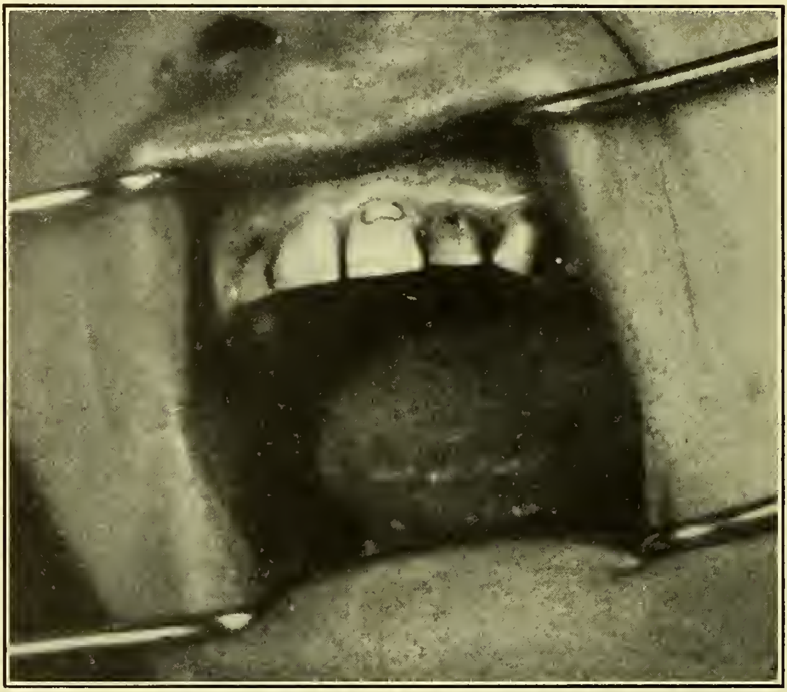


FIG. 726.—Gingival third cavities on the right central and lateral and the left cuspid; a defective silicate filling on the left central and a gold filling on the left lateral. Ideal cases for insertion of porcelain inlays.

THE DIRECT METHOD

Cut the foil into proper size and shape, allowing sufficient excess to extend three or four millimeters beyond the margins of the cavity. Force the matrix carefully into the cavity, beginning first in the center of the floor, avoiding tearing and crumpling. By means of small pieces of wet cotton, spunk or chamois and ball-pointed inlay pliers, or smooth burnishers number 60; 2; 3; 4; 33; and 34 carefully adapt it to place. The cotton or other materials and the burnishers are used to adapt the matrix to all parts of the cavity, working from the center toward the lateral walls. After this is accomplished, gently burnish the platinum against the margins and iron out the excess apron over the adjoining surfaces. In large and difficult matrices the excess platinum may be folded back over itself all around its periphery in order to strengthen it in handling. Now, with the matrix full of cotton or spunk, and partially adapted, stretch a thin linen tape over it. Holding it firmly in position, burnish over the tape with a ball burnisher to improve the adaptation of the platinum to the cavity walls, margins and adjacent tooth surfaces. Now remove the tape and cotton or spunk pledgets, and stretch a small strip of rubber dam over the matrix, which is still in position. Burnish thoroughly, being sure that the margins are perfectly adapted, when the dam is removed and the matrix is completed. The use of the linen tape and rubber dam prevents to a large extent the development of springiness in the platinum which might result from direct contact of burnishers. If a "spring" develops in the platinum during the procedure, annealing should be resorted to. Figs. 727 and 728.

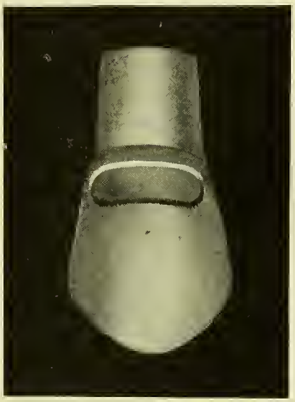


FIG. 727.—Class V cavity in a cuspid, prepared for porcelain inlay.

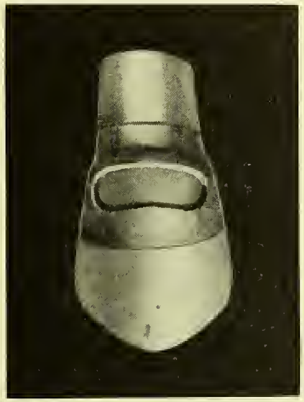


FIG. 728.—Platinum matrix adapted to place.

THE INDIRECT METHOD

Taking the Impression.—An impression of the cavity is first taken in modeling compound. From this an amalgam die is secured. The matrix is then burnished over the surface of the cavity in the compound impression, then transferred to the amalgam die, burnished to it and swaged in a swaging apparatus.

For **Gingival Third Cavities.** In securing impressions of cavities extending well under the marginal gingiva, it will often be necessary to force the gingiva away for a few days with guttapercha. This is also the case where the matrix is burnished into the cavity in the direct method. For securing the impression, trim a Kerr modeling compound stick into the shape of the cavity, heat the end in the flame, dip in water at a temperature of about 160°F. and force it while soft into the cavity and toward the gingiva, holding it at an angle of 45 degrees from the long axis of the tooth. Now, while the compound is still soft, maintain the pressure and bring the compound stick to a position at a right angle (90 degrees) to the cavity. In both methods, the compound must be thoroughly chilled before removal.

Doctor Alfred Walker of New York City has devised an ingenious and simple method of taking impressions of gingival third cavities. A small strip of rather stiff platinoid or German silver is trimmed and shaped to conform to the contour of the surface on which the cavity is located and to extend under the gingiva, so that it covers the gingival margin of the cavity and holds the gingiva away from the margin. A hole is now drilled in the impression tray the size of the cavity. The tray is now coated on its concave side with a thin layer of softened compound and forced into position on the tooth. A tapered compound stick is next softened, forced through the hole previously cut in the tray, into the underlying cavity, when it is chilled and the tray containing the impression is removed. Figs. 729, 730 and 731.

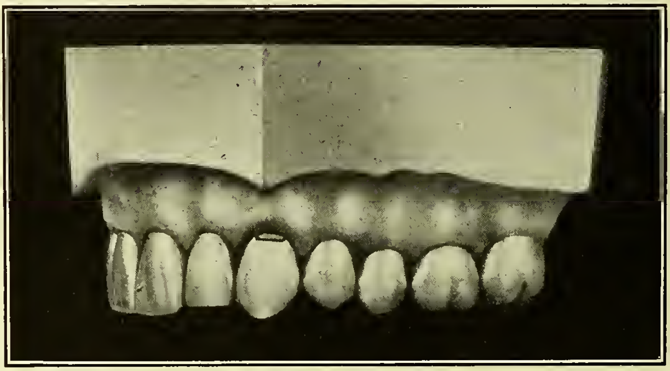


FIG. 729.—Class V cavity ready for adaptation of tray and impression material.

Impressions of **Class III** and **Class IV** cavities are also taken with specially devised trays, made for the case, of platinoid about 28 gauge. The platinoid strip is cut of sufficient width to cover the cavity and long enough to furnish a convenient handle. Small holes are drilled in the end of the impression tray to hold the modeling compound in place, and it is then bent at a right angle. Sufficient separation to admit of entrance of the tray and impression material is necessary. For Class IV cavities, the sides of the tray should also be bent to cover the labial and lingual walls and the tray should be inserted from the

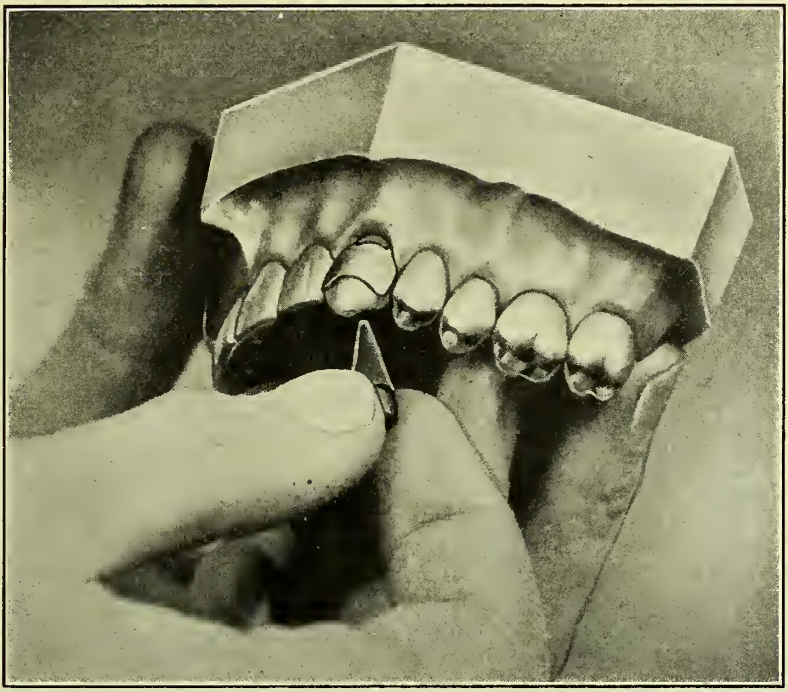


FIG. 730.—Dr. Alfred Walker's method of securing an accurate impression of a gingival third cavity. The improvised metal tray is in place and the modeling compound cone is ready for insertion.

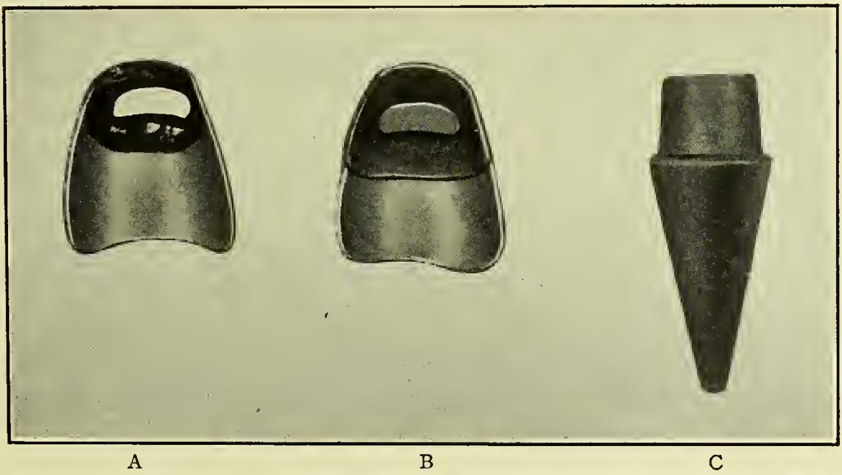


FIG. 731.—A. Improvised impression tray with hole drilled and soft modeling compound adapted to its under surface. B. Impression taken and tray and impression removed. C. Modeling compound stick.

incisal direction. In either case, the modeling compound is heated, placed in the tray, carried to position, chilled and carefully removed. In large Class III cavities, revealing both labial and lingual surfaces, the direct method may often be more conveniently used, on account of the difficulty of securing a correct impression.

Impressions of **Class II Cavities** may be obtained with properly trimmed seamless copper bands as described for the gold inlay. The same is true for proximo-incisal cavities with an incisal step, using these instead of the special tray just mentioned.

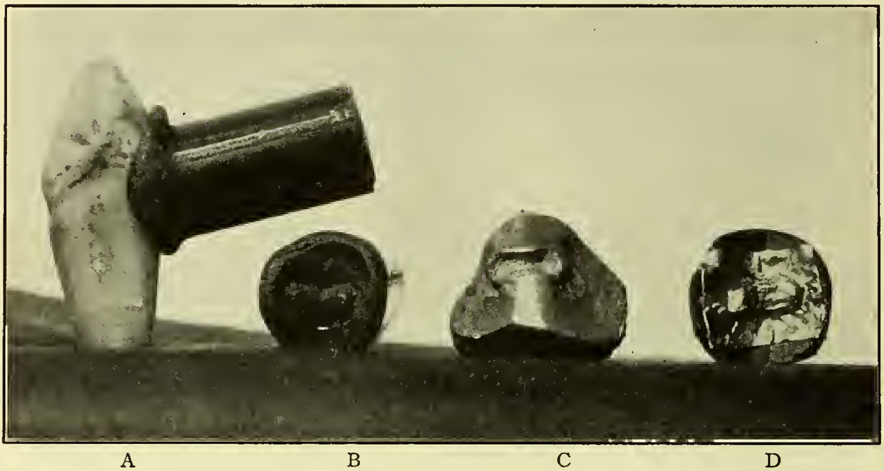


FIG. 732.—Securing the impression, die and platinum matrix in the indirect method. A, taking the impression with a modeling compound stick. B, impression taken. C, amalgam die properly trimmed. D, platinum matrix burnished on modeling compound impression before swaging on die.

Securing the Die and Matrix.—After obtaining a correct impression, an amalgam die is secured from this in a similar manner to that described in the previous chapter for making gold inlays by the indirect method. If, on securing the amalgam die, the modeling compound impression has not been marred or destroyed, the platinum matrix material may now be carefully burnished over the compound impression of the cavity and then after annealing be transferred to the amalgam die, burnished to it and swaged in a swaging apparatus. Fig. 732. If the compound impression has been destroyed, the matrix may then be constructed on the amalgam die, which has been mounted on a convenient base, if necessary, in a similar manner to that described for the direct method. Or, in Class V cavities, an impression of the cavity in the amalgam die may be taken with a modeling compound stick, the matrix material loosely adapted to the impression and then the compound stick impression carrying the platinum foil may be carried into the cavity in the amalgam die. After peeling the edges of the matrix away from the modeling compound, remove the stick, leaving the matrix material in the cavity in the die. Following this, the perfection of the adaptation of the matrix to the die is completed after the previously described method. In some instances, a soft pine stick may be trimmed, forced into the cavity in the amalgam die until it fits, the matrix adapted to that, and fitted to the cavity, as in the previous instance.

In many cases it will be safe to try the completed matrix in the mouth and perfect any inaccuracies found, before proceeding further. In simple cases, this is often not necessary. Following the completion of the matrix, the next step in the construction of the inlay is the selection of the shade and the mixing and fusing of the porcelain.

COMPOSITION AND GENERAL CHARACTERISTICS OF PORCELAIN

The general composition of porcelain for inlays is as follows: (1) Basal ingredients, such as kaolin, feldspar and quartz or silica; (2) fluxes, such as sodium borate, sodium and potassium carbonate; and (3)-pigments, such as gold, platinum, purple of Cassius, oxid of cobalt, titanium, iron, tin and silver.

Basal Ingredients.—These substances are ground into fine powder, mixed together in varying proportions, depending on the qualities of the different products. The ground feldspar when fused melts to a glass, makes the porcelain vitreous, cements together the more refractory materials and increases translucency. The kaolin gives plasticity, stability of form and shape to the mass, while the quartz or silica acts as a filler or non-plastic material, imparting increased stiffness and strength to the mass and fuses at a high temperature.

Fluxes.—These substances promote fluidity in fusing and remove impurities.

Pigments.—Oxid of titanium imparts a creamy yellow color; cobalt exhibits blue tints; iron produces browns; tin and gold (purple of Cassius) give the pink to gum colors; metallic gold forms reddish brown shades; and platinum imparts grayish tints.

Classes of Porcelain.—There are two general classes of porcelain used in inlay construction, viz.: high and low fusing. Some manufacturers also supply medium fusing bodies. High-fusing porcelains usually require five minutes or more to fuse at 2,100 to 2,400°F., while low-fusing porcelains require less than five minutes and fuse below 2,100°F.

A porcelain inlay usually requires several bakings in the furnace. The first of these bakings is known as the biscuit fuse. By the "biscuit fuse" is meant the act of heating the porcelain sufficiently to obtain shrinkage, but not enough to glaze it. The first bake should never exceed a low-biscuit fuse, subsequent bakes being fused to a higher temperature, but the final glaze being not completed until the last bake. If this is neglected, over-fusing, porosity, loss of strength and proper shade may result. Porcelains have a tendency to spheroid when over-fused.

All porcelains shrink on fusing. Usually the finer-ground the powder, the lower the fusing point and the greater the shrinkage. The larger and thicker the mass, the greater the time necessary to fuse.

High-fusing porcelains shrink 15 to 25% of their volume; low fusing from 20 to 35%.

SELECTION OF PORCELAINS

Among the prominent dental porcelains on the market may be mentioned those of the S. S. White Dental Manufacturing Company, H. D. Justi and Son, Twentieth Century and the Jenkins low fusing bodies. The S. S. White Company now supplies three porcelains, viz., low-fusing, medium-fusing and high-fusing. The fusing-points for these are approximately 1,700°F. for the low, 2,300°F. for the medium and 2,400°F. for the high. The fusing point of Jenkins' Low Fusing Porcelain is approximately 1,550°F. For general use the S. S. White medium fusing porcelain has a wide range and serves the purpose very well for all inlays and most jacket crowns. It fuses at a reasonable temperature and has adequate strength and translucence. For jacket crowns requiring great strength, the high fusing porcelain should be used. Usually it is best to confine oneself to one porcelain, with which thorough familiarity of the working properties may be gained through repeated use, rather than use several types of different fusing points and characteristics.

In the S. S. White porcelains thirty-two colors in the three different porcelains are available. They are numbered from 31 to 62 inclusive and lettered "L," "M," and "H," depending on whether they are low, medium or high fusing. These colors are grouped as shown on p. 645.

Colors 34, 35, 36, 41, 45 and 46 are intended for the foundation or basis of the inlay or jacket crown, and also for shading the gingival portion. These are rather intense colors and not suitable for incisal coloring, which usually requires lighter shades. A natural tooth usually presents a darker color at the gingival third, a lighter at the incisal third and a blending of the two at the middle third. This should be remembered in selecting shades for inlays or jacket crowns. To produce these variations two or more colors are selected and blended together in definite proportions, placing them in their proper positions as indicated, to obtain the desired effect. The gingival foundation or body color should be applied first, this becoming the base or underlying color, over which is added other colors to produce shading in different positions. Inlays usually require at least two colors to produce natural and translucent or life-like effects, while jackets often require three or more, placed on and baked in separate layers.

COLOR GROUPINGS

Group	Numbers
1—Oranges	31, 32, 33, 34, 35, 36
2—Yellows	37, 38, 39, 40, 41
3—Browns	42, 43, 44, 45, 46
4—Greys	47, 48, 49, 50, 51, 52, 53
5—Pinks	54, 55, 56, 57
6—Modifying	58 white, 59 greenish yellow, 60 red, 61 blue, 62 black.

SELECTION OF SHADES

Proper shades are selected by taking the color of the tooth in the mouth, with an ordinary shade guide. This, with some, is often a difficult procedure. Some individuals seem to possess an intuitive discernment or natural instinct for colors and have an "artistic eye" and an esthetic sense. Others are partially or completely lacking in this, as a natural gift. However, color perception may be improved to a degree by anyone who is willing to devote the time and study to its development. In the selection of shades for this work refraction of light, translucency, influence of cement under the inlay or jacket, and irregularities of surface must be understood and evaluated. Space will not permit a discussion of the theory of colors and of light. These subjects are included in courses on physics.

The color of the dentin is the controlling factor concerned, the enamel having very little influence. The basic dentin colors are yellow and grey and it is first necessary to determine whether yellow or grey dominates or whether, as in some instances, there is a nearly equal proportion of each. Then the shade variations of the basic colors present must be determined. The shade of the natural tooth is largely produced by the effect of the relatively non-pigmented enamel, overlying a pigmented dentin, and may vary, depending on the overlapping of several shades, one over the other. Several additional factors may modify conditions in attempts to select or match shades. These are (1) the diameter and density of the dentin, (2) the effect produced by the influence of the basic dentinal color on the overlying enamel; (3) degree of polish of the enamel; and (4) presence of hypoplasia or other irregularities, facets, fractures, etc. The entire dentin usually presents a dominant shade and this must be determined and taken into consideration. However, localized influences must be considered, such as reflection of light from adjoining surfaces, change of shade from abrasion, checks in the enamel, and removal of the pulp.

In taking the shade, the patient should sit in the upright position before a good light. Exclude all cross lights and avoid, if possible, the light of dark or cloudy weather. Stand directly in front of the patient and with the shade guide moist and the surfaces of the teeth lubricated with saliva, test the shades at the incisal, middle and gingival third, with the lips in repose, smiling and retracted. Note the general dominating shade of the entire denture and any modifications of this in the tooth being operated on from the local conditions mentioned. Now determine the dominating shade, whether yellow or grey or a combination of both. Then analyze the shade of the shade-guide tooth finally selected as most nearly matching the individual requirement, in such a manner that the basic and the modifying shade in the porcelain body to be used may be determined by number or letter as used by the manufacturer. Having determined this and analyzed the case in hand from the effect of the influence of any local modifying factors, such as vitality or non-vitality, thickness, normal fullness, abrasion, enamel checks, and other environmental factors, the next step is to determine the proportion of the porcelain shades to be used in producing the foundation, gingival, incisal or occlusal shades. In selection and blending of shades, it is well to remember that the finished inlay should be slightly darker on labial and buccal surfaces, and a trifle lighter on proximal surfaces. The manufacturers publish tables showing combinations of shades indicated for matching shade guide teeth, which are of great assistance. However, most of them must be considered as only approximate guides to proper selection and blending. A thorough familiarity with the porcelain colors, through long experimentation and practice is necessary to produce in all cases artistic and natural results.

Recognizing the difficulties for the average practitioner, the S. S. White Company have devised an improvement on the previously used blending charts in the form of ingenious formula selectors, one of which is illustrated in Fig. 733. By manipulating the rotary dial, the serrated edge of which is seen on all four sides of the Selector, the colors and proportions of S. S. White, Twentieth Century and Justi porcelain bodies will be shown on the face of the Selector. Two of these are provided for the purpose. Both gingival and incisal colors are indicated. Those to be used for the first, second and third bakes, where blends are necessary are also shown.

In porcelain work it will occasionally be necessary to use a combination of high, medium, or low fusing powders. In doing this, the fusing point of the mixtures used will be different, depending on the components and proportions of the various mixtures. A graph may be obtained showing the fusing temperatures of various mixes of S. S. White High, Medium, and Low fusing porcelains. A study of this graph shows, for instance, that the fusing point of Low fusing body may be raised to any temperature. As an example, 80% Low, mixed with 20% High will fuse at 1,820°F., while 10% High and 90% Medium will fuse at 2,380°F., etc. Two readings for temperatures are given for each type of mixture, viz. one in which no holding time in the muffle ot the baking furnace is allowed and another of lower temperature if holding time is allowed.

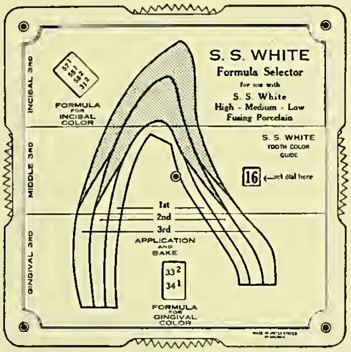


FIG. 733.—Celluloid formula selector for selecting proper shades in porcelain work.

MINERAL STAINS AND FINISHING GLAZES

To improve the shade of a finished piece or to reproduce colors the result of pathologic conditions, such as hypoplasia, enamel checks and similar effects, mineral stains are provided by the manufacturer for this purpose. Often it will be necessary to grind a finished piece, which grinding removes from the surface the glaze incident to fusing the porcelain. This glaze cannot be restored by polishing. In some cases, the removal of this glaze improves the appearance of the work when placed and lubricated with saliva. In other instances, its translucent, life-like appearance is lost, or it may appear slightly off color.

The baking on to its surface of a finishing glaze supplied by the manufacturers will restore it to proper appearance.

Stains may be obtained, both high and low fusing, the high temperature stains fusing at about 1,900°F. and the low at approximately 1,600°F. They may be mixed and painted on to the surface in a thin layer with a camel hair brush and fused in the furnace. They are supplied in brown, yellow, grey, blue, white, green, pink and black colors and may be mixed in different proportions to secure the desired effects. In some instances, better results are obtained by grinding indentations, grooves or other characteristics present in other teeth of the same denture, applying a stain and following this with a glaze or with a porcelain of lower fusing point. White spots, tobacco stains, mottled enamel and other defects may thus be reproduced.

Glazes are obtainable, fusing at approximately from 1,600°F. to 2,000°F. A small quantity of the powder should first be rubbed into any pits or porosities showing on the surface as a result of the grinding and then fusing it. Following this, a very thin mixture of the powder in distilled water is painted on and fused, as a result of which the natural glaze is restored. Glazes also may be used in combination with stains as described in the foregoing paragraph.

Bibliography

Capon, W. A.: Porcelain—Its properties, Jour. Amer. Dent. Assoc., vol. XIV, 1927, p. 1459.

Vehe, W. D.: Porcelain—Technic as it relates to the inlay, Jour. Amer. Dent. Assoc., vol. XIV, 1927, p. 1465.

Jenkins, N. S.: Porcelain inlay in Europe, Dental Cosmos, vol. LVIII, 1916, p. 269.

LeGro, A. L.: Porcelain inlay technique, Dental Items of Interest, vol. V, 1928, pp. 19, 104, 182, 260, 351, 436, 508, 623.

LeGro, A. L.: "Ceramics in Dentistry," 2nd ed., Dental Items of Interest Publishing Co , New York, 1929.

McBean, C. O.: Porcelain as applied to dentistry, Jour. Amer. Dent. Assoc., vol. XIV, 1927, p. 138.

Huff, Malvern D.: Porcelain inlays and their substitutes, Jour. Amer. Dent. Assoc., Aug. 1928, p. 1505.

Parker, C. G.: Porcelain jacket crowns, Jour. Amer. Dent. Assoc., Aug. 1928, p. 1518.

CHAPTER XXIII

CERAMICS (*Continued*)—FURNACES—MIXING AND FUSING PORCELAIN—THE INLAY—THE JACKET CROWN

PORCELAIN FURNACES

Modern electric furnaces consist of the muffle in which the baking is done, a rheostat to control the current and a pyrometer to indicate the temperatures available. Fig. 734. The use of a pyrometer attachment was first instituted by Doctor Weston A. Price of Cleveland and resulted in great improvement in porcelain technic. The correct handling of the furnace comes only with experience. The muffle should be cleaned with a chip blower or compressed air and kept free of dust of all kinds, else it may be burnt out. In heating the muffle, the rheostat should be adjusted to the first button and allowed to heat to its highest capacity on that button before moving to the next. If the controller is turned to higher contact buttons before the maximum heat obtainable on previous buttons has been reached, or if several buttons are jumped, the fine platinum coil of the muffle is likely to be burnt out. Pedestals, saggers and boats of clay or fused silex are provided for resting the work on and

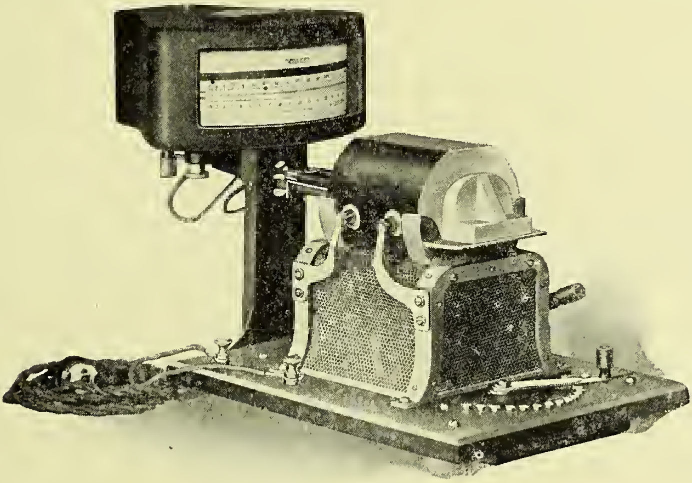


Fig. 734.—S.S.W. Electric Pyrometer Furnace.

handling during fusing. Clay doors are also used for closing the mouth of the muffle during firing.

In using the furnace, the fusing temperature of the porcelain being used and the time required to bring the heat to the desired amount have both to be considered. The latter consideration will vary with different types of furnace and will have to be tested by experimentation and from printed instructions of the manufacturer. Experience with the furnace and the pyrometer will enable the operator to definitely formulate the time required. The baking should begin with a hot furnace. It should previously have been determined on what button of the rheostat, after the muffle has been heated up, the porcelain being used will fuse within a reasonable time. In increasing the heat, the controller should remain on the first and each succeeding button for a given time, previously determined, until the maximum heat of which each button is capable has been obtained. The necessary time for each button as previously determined should be given it in each succeeding bake, always employing that given time, as registered by a clock or watch, and fusing on the button previously determined upon as giving the necessary temperature to produce a proper glaze. Two minutes for each button is the average or approximate time required, or 90 seconds for each 100°F. rise in temperature. Time and heat temperature are of equal importance in fusing porcelain. Definite temperatures or registers on the pyrometer must be attained during definite periods of time. If medium or high fusing porcelain is used, the furnace may be carried to 1,600°F. on the first button before placing the work in the furnace. The LeGro method consists in raising the temperature, after placing the piece in the furnace, by increasing the heat 100°F. each 90 seconds until the desired temperature is reached. If necessary, the control may be carried backward or forward to accomplish this result in the time mentioned.

Mixing and Fusing the Porcelain Inlay.—Immaculate cleanliness is essential to good work in this as in all specialties of dentistry. Clean muffle, work bench, instruments and hands will prevent contamination of the work. Air contamination with coal dust, smoke or other impurities should also be avoided, by closing the window, if necessary, for the same reason. The matrix having been prepared, the shade selected, the proportion and number of powders determined, the mixing and baking may now be proceeded with.

The powders selected may be mixed to a thick creamy consistency on clean glass slabs by means of a clean spatula, with distilled water.

The *saturation lubrication method*, which excludes air bubbles, consists in placing the powders in separate Dappen glasses (Fig. 735), adding sufficient distilled water to cover them, when the excess water is poured off after two minutes, without spatulation, leaving the mix to the proper consistency and without air bubbles. This is considered by some as superior to the old method. Lay on the body, and fuse in the furnace in layers to a biscuit bake, 60° to 100°F. lower than glazing temperature, slightly jarring the material into the matrix, and absorbing excess moisture on bibulous paper, before placing in the furnace.

Porcelain shrinks on firing, with the result that care must be taken to avoid its drawing away from the lateral walls and margins of the matrix. Three methods are recommended to prevent this, known as the ditching, cross-cutting, and layer methods. The *ditching method* consists in filling the matrix and building to full form with the colors distributed as indicated. Then a ditch is cut with the inlay carver into the porcelain around the inner margins of the matrix, leaving some porcelain on the margins, when the case is then fused to a biscuit bake. Since the porcelain shrinks towards the center the ditch will be enlarged, but the margins will remain partially covered. Now the ditch is filled with fresh porcelain, the margins again covered and the case fired a second and a third time if necessary, to complete the fusing and to bring the inlay to proper form. The *cross cutting method* is accomplished by filling the matrix as before and cutting a cross through the center of the porcelain to the matrix. When fused, the sections of porcelain separated by the cross will shrink toward the margin rather than toward the center. In the *layer method* the porcelain is built on in successive layers, which are

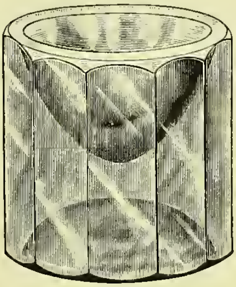


FIG. 735.—Dappen medicament glass.

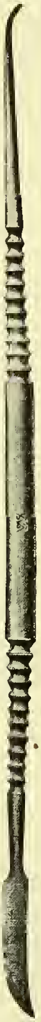


FIG. 736. Inlay carver No. 5.

built higher in the center, each layer being fused to a biscuit bake before adding another, until when the final layer is placed the entire inlay is fully fused and glazed. By hilling up the layers, each is shingled over the other at the margins and shrinkage avoided. In complex cavities, when the teeth vary in color at the cervix and cutting edge, the body may be built in *sections* instead of layers. Continue adding the body and partially fusing until the matrix is nearly full, when the last layers of enamel may be added, carved to form with an inlay carver, (Fig 736), and brought to a full glaze.

Avoid putting porcelain, when wet, into a hot furnace on account of the danger of producing checks in the porcelain. Before carrying it into the furnace, lay it near the open door of the muffle until dry. A small tear in the matrix, provided it is not on the margin, will do no damage, as the porcelain, if it runs through, may be removed with a fine brush before fusing. All excess porcelain should be removed from the margins with a brush, before fusing. The baking should be continued until proper contours are restored, trying in the mouth as often as is necessary to accomplish the result. The platinum matrix should be handled very carefully with pliers to prevent distortion. After the final fusing, try the inlay in the mouth, and before removing the matrix, grind to the proper contour and occlusion with a fine stone, if necessary. Now carefully remove the matrix. This is accomplished by placing the inlay and matrix in alcohol or water, then carefully peeling the matrix away, first from the margin, and later from the body, to prevent chipping of the margins.

The under surface of the inlay may now be etched if desired, to provide for better retention. To do this, imbed the contour surface of the inlay in wax, and seal the margins with a hot spatula to prevent contact of acid with the margins. Dip a sharp wood stick into the bottle containing hydrofluoric acid, and paint the exposed side of the inlay with the acid for two minutes, thus etching or roughening the inlay, to provide for a better grasp of the cement. Then flood with water, remove the wax, boil for a few moments in a weak solution of sodium bicarbonate to neutralize the acid, wash again with boiling water, then dry, when the inlay is ready to set. If any small white particles remain on the inlay as a result of the acid, blow them away with the chip blower or compressed air.

CEMENTING THE INLAY

After thoroughly drying the cavity and inlay, cover the walls of the cavity and the under surface of the inlay with a good, white, sticky cement, mixed to a creamy consistency. Cement matched closely to the color of the inlay will sometimes produce better effects in translucency than white cements. Translucent Kryptex is also used by some for the same purpose, but its low adhesiveness is a disadvantage and claims have been made that it endangers the pulp. Press the inlay firmly to place with an orange-wood stick, tapping until firmly seated, when it should be held or wedged to place until the cement is set. Finish down at a subsequent sitting, removing excess cement, dressing down overhanging margins, and polishing with fine stones and discs.

THE PORCELAIN JACKET CROWN

A porcelain jacket crown is a thin veneer of porcelain, fused by the dentist for individual cases, which replaces the enamel of the tooth, previously removed for its reception, and which so perfectly fits the underlying dentin, and so securely rests on a shoulder prepared for its reception under the marginal gingiva, that, when cemented to place, the anatomical form, esthetic appearance, and physiologic functions of the tooth are properly restored. Fig. 737.

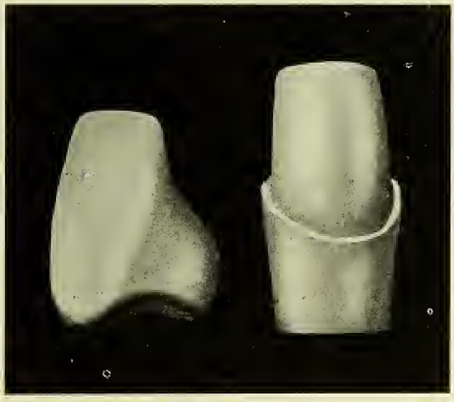


Fig. 737.—Porcelain jacket crown completed and ready to cement on prepared root

Advantages, Disadvantages and Indications.—When efficiently made, this is one of the most beautiful, artistic and useful restorations in the entire realm of dentistry. If improperly constructed, it is likely to produce inartistic effects, to endanger the vitality of the underlying pulp, to produce irritation and disease of the gingival tissues, or to be subject to early fracture and loss. The gingival tissues adjust themselves well to this glazed material, if properly fitted, and a normal healthy pulp is protected by its low conductivity, if the cutting incident to the preparation of the tooth for its reception is not carried in too close proximity to it. The porcelain jacket crown may be used (1) on centrals, laterals or cuspids in which proximal cavities involve both angles; (2) in many cases on the same teeth where a single extensive proximo-incisal cavity for esthetic reasons prohibits the use of gold; (3) on badly stained anterior teeth which cannot be successfully bleached; (4) on hypoplastic, malformed and mottled teeth exposed to view; (5) on fractured anterior teeth which cannot be successfully restored otherwise, and (6) even in some instances on bicuspids or molars, if for esthetic reasons the patient desires it and the skill of the operator will enable him to make an efficient and strong restoration. However, it is seldom used on posterior teeth on account of the difficulties of construction and its comparatively low crushing resistance. It may be used on either vital or non-vital teeth. One of the chief advantages of this type of restoration is preservation of the vitality of the pulp, most other forms of crowns requiring pulp removal with its attendant and subsequent dangers. The chief disadvantages it possesses are the difficulties incident to its construction and the skill and artistic ability required in producing proper blending of shades and restoration of tooth form. Figs. 738 and 739.

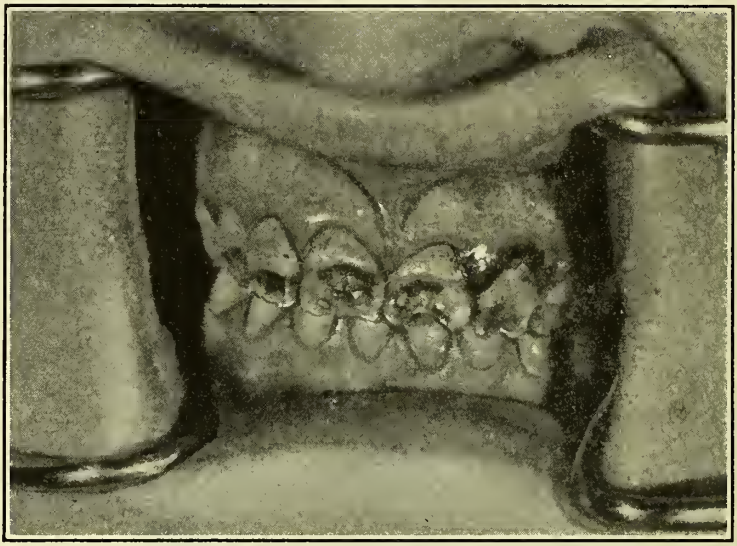


FIG. 738.—Hypoplasia and caries of the upper anterior teeth. An ideal case for adjustment of porcelain jacket crowns.

Preliminary Considerations and Procedures.—An intimate knowledge of dental anatomy is important in reproducing natural tooth form in these cases, as in all other fields of restorative procedure. The dentist must not only know tooth form, but must be able to reproduce it. This attainment should previously have been acquired in the course in dental anatomy, through repetition in carving tooth surfaces in soft and hard materials.

When a case presents, impressions and correct study models should be made of the tooth involved and those approximating it, in order that the typal form and any particular markings may be reproduced in the restoration. Roentgenograms should be made for a study of the size and location of the pulp chamber, as well as the condition of the root and surrounding tissues.

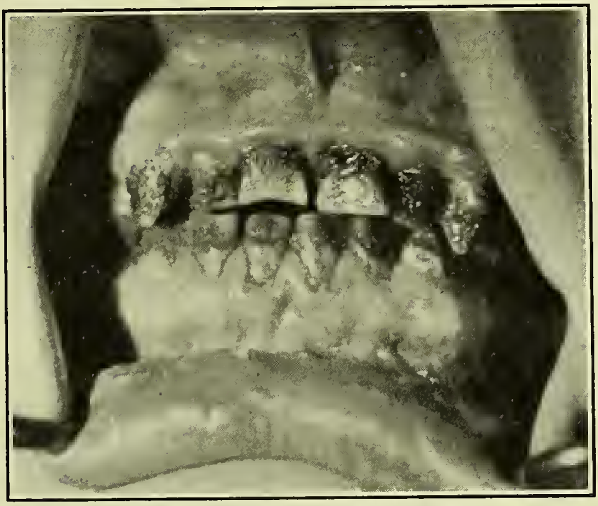


FIG. 739.—Agnesia or absence of enamel. A similar abnormality was reported for all females in this family as far back as the grandparents—No males are affected. (Courtesy of Dr. Samuel C. Miller.)

Preparation of the Tooth for Reception of a Jacket Crown.—Description of the technic for a central incisor will suffice for illustrative purposes. The instruments used are illustrated in Figure 740. They consist of one each—

"Heatless" stone, No. 11, S.S.W.
Carborundum disk (safe side), ⅞ inch.
Carborundum stone No. 5.
Chayes stones, 27 and 34.
Burs, No. 557 and 957 (flat-end fissure and end-cutting).
Inlay bur, No. 3, straight and R.A., ground to half length, S.S.W.

The preparation of the crown of the upper left central incisor may be divided into definite steps as follows:

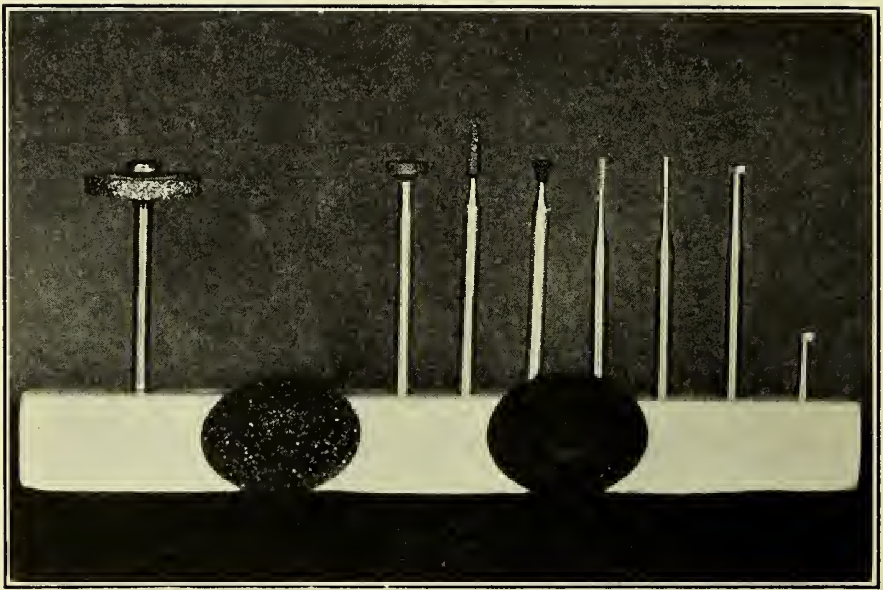


FIG. 740.—Left to right.—No. 11 "heatless" stone; safe side ⅝" carborundum disc; Carborundum stone No. 5; 27 and 34 Chayes stones; S.S.W. No. 557 and 957 burs; S.S. W. inlay burs No. 3 ground down to half length.

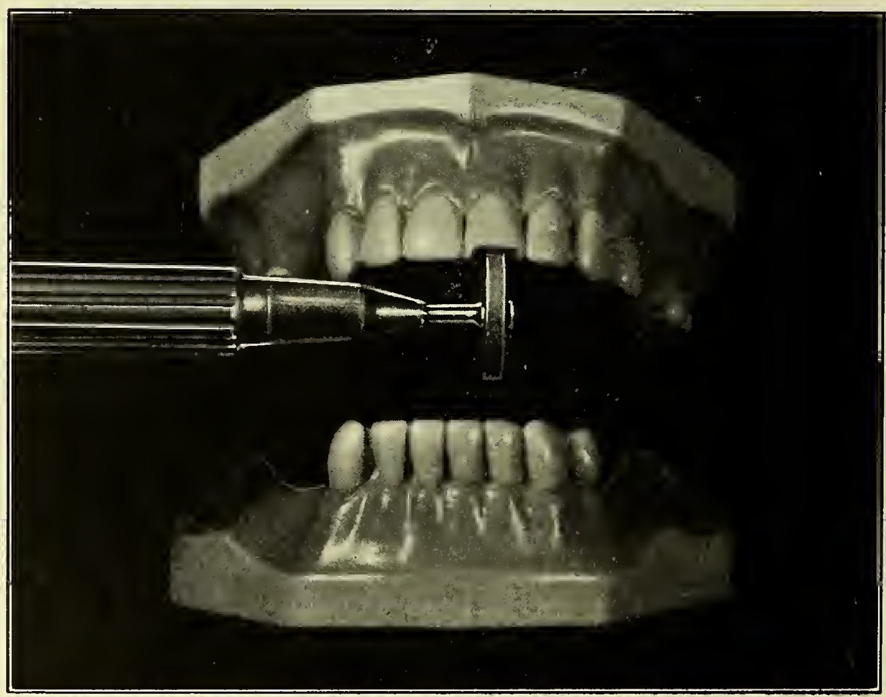


FIG. 741.—Incisal edge removed about 2 mm. and beveled at right angles to stress. Edges of enamel left to facilitate starting of the disc in the next step.

1. With the carborundum stone number 11, remove the central and part of the mesial and distal thirds of the incisal edge, for a depth of approximately 2 millimeters. The cutting should be more at the expense of the lingual than the labial surface, so as to place the incisal seat for the restoration at nearly right angles to the stress, when the lower teeth are brought into occlusion. The mesial and distal angles are not touched at this time, being allowed to remain to facilitate starting of the disk in the next step. See Fig. 741.

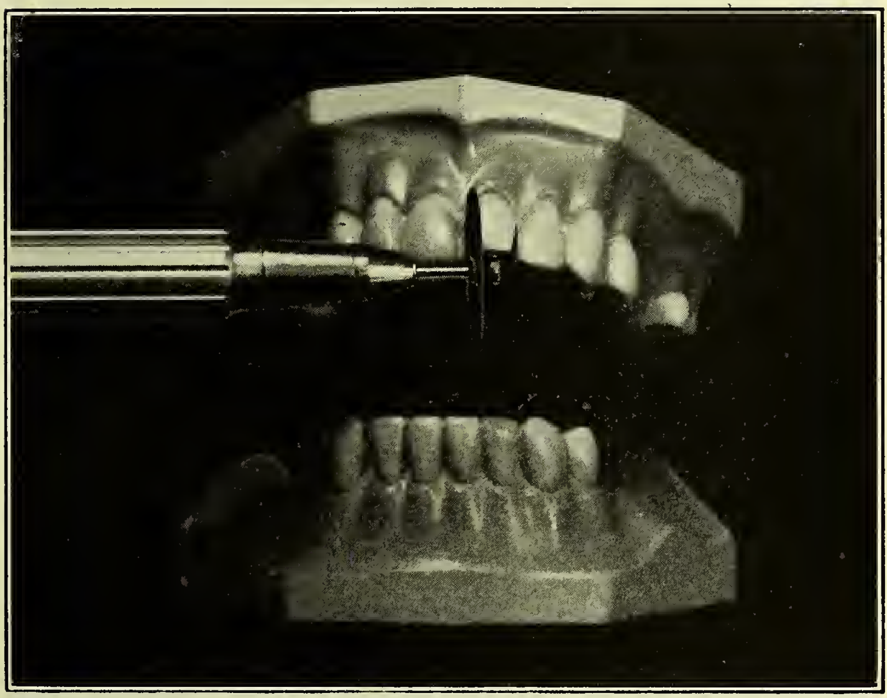


FIG. 742.—Enamel being removed with a safe side disc on the proximal sides. Left side removed, right side being removed. Note the angle of the disc.

2. With the safe side ⅞ inch disk, inserted on the incisal cut previously made, and close against the angles, remove the enamel of the mesial and distal surfaces. The cutting is carried slightly short of the marginal gingiva, and the disk is inclined so as to produce slight convergence toward the incisal, of both proximal surfaces. See Figs. 742 and 743.

3. With carborundum stone number 11, remove the enamel from the middle and incisal thirds of the labial surface, keeping away from the gingival third at this time. Fig. 744.

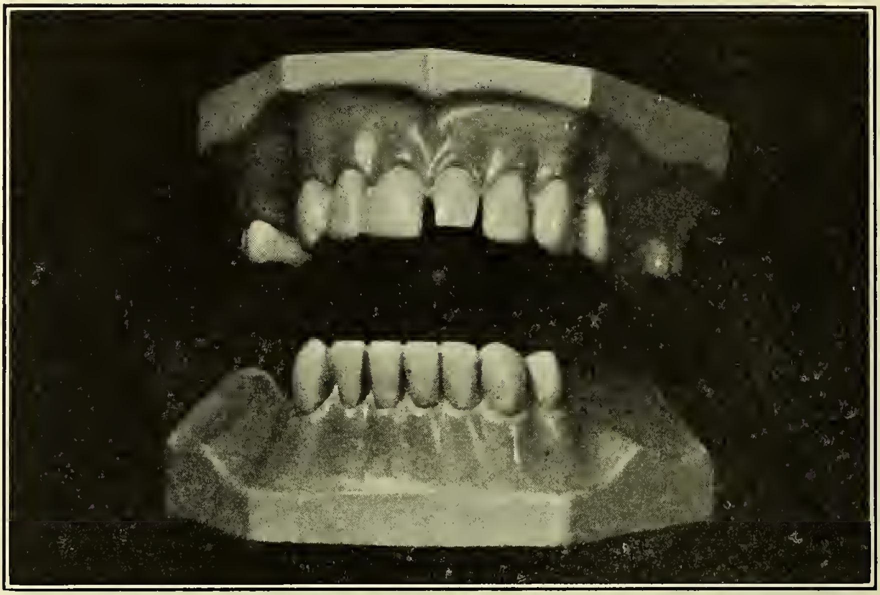


FIG. 743.—Enamel removed from the incisal and proximal surfaces. Note slight inclination of the proximal surfaces.

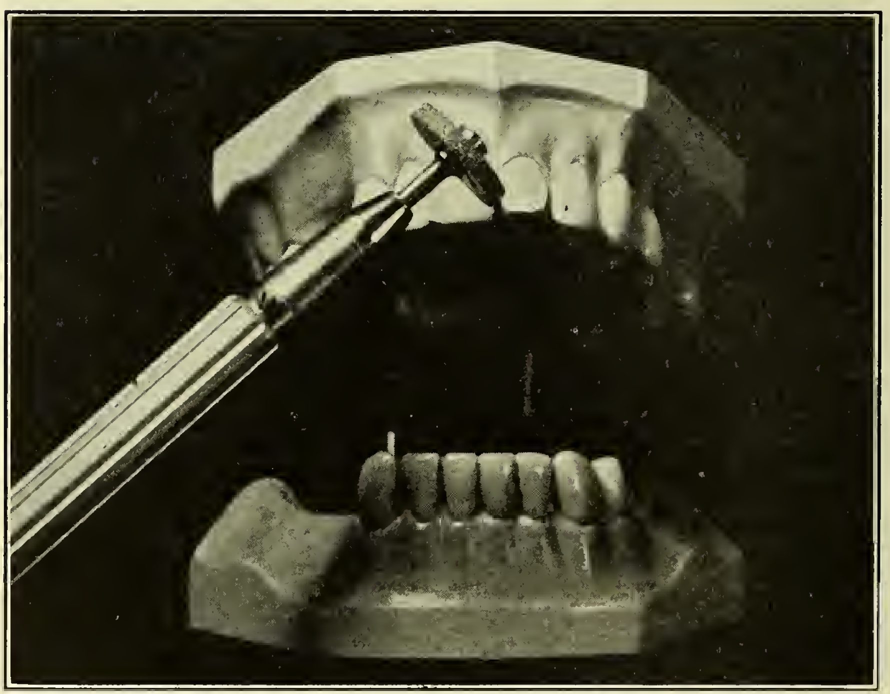


FIG. 744.—Starting the removal of enamel on labial surface. Heatless stone No. 11.

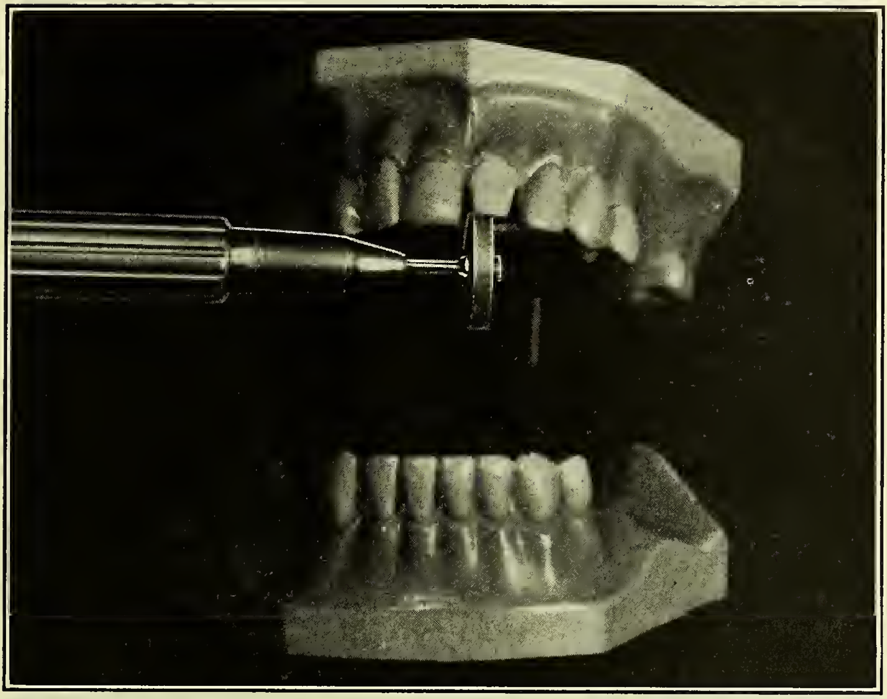


FIG. 745.—Enamel being removed on the lingual surface. Labial view.

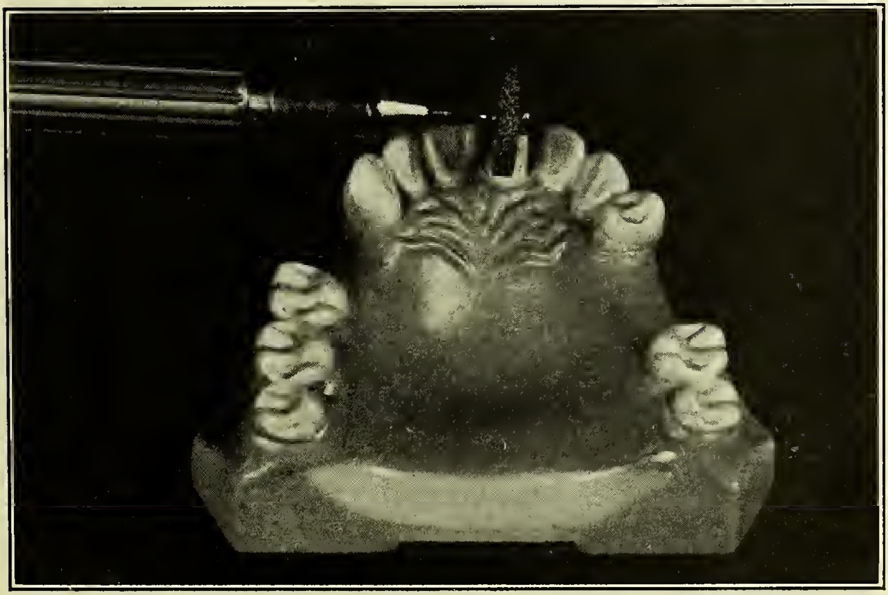


FIG. 746.—Enamel being removed on the lingual surface, lingual view.

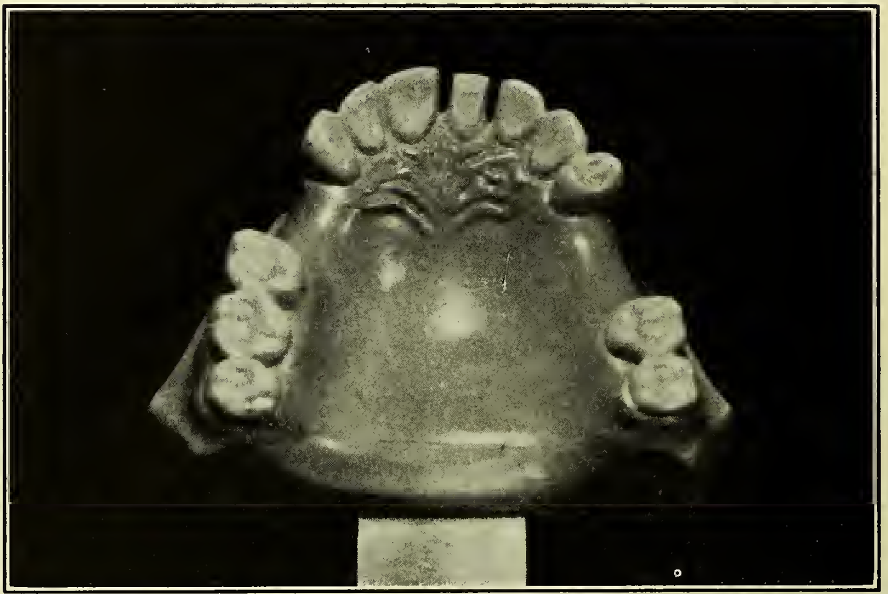


FIG. 747.—Lingual view after removal of enamel. Note bevel of the incisal edge.

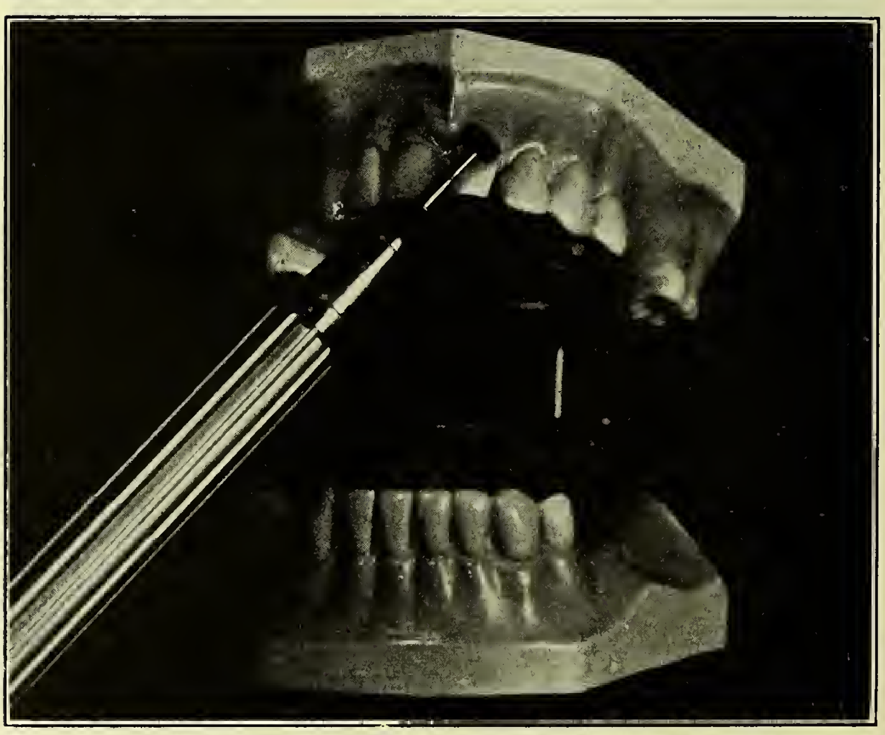


FIG. 748.—Removing balance of enamel with smaller stone No. 5, near marginal gingiva.

4. With the same stone, remove the enamel from the incisal third of the lingual surface, cutting a flat seat in that location at right angles to the line of stress. Figs. 745 and 746.

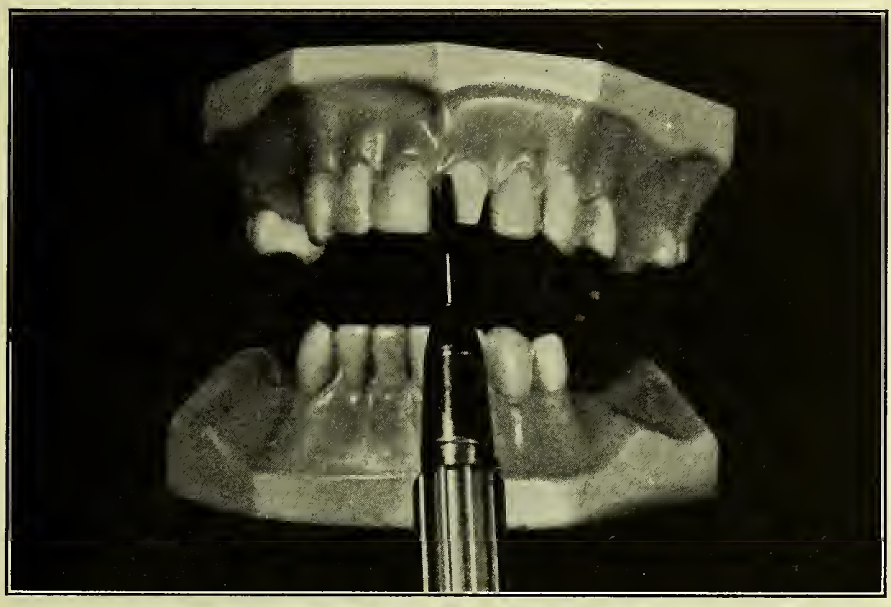


FIG. 749.—Rounding over sharp angles. Stone No. 27.

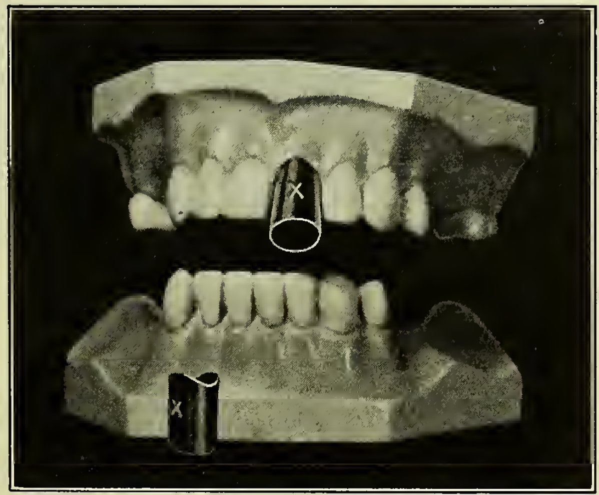


FIG. 750.—Copper bands are now fitted, festooned and laid aside for impressions to be taken later. An x designates the labial surface.

5. Now with the same stone remove the enamel from the middle third of the lingual surface, cutting in a plane with the lingual surface. Note the bevel of the incisal portion as seen in Fig. 747.

6. With carborundum stone number 5 remove the balance of the enamel in the gingival thirds of both labial and lingual surfaces, avoiding wounding the gingiva. Fig. 748.

7. With stone number 27 remove the angles joining the labial and lingual with the proximal surfaces and remove any convexity remaining on the labial surface or the gingival part of the lingual surface which would prevent the withdrawal of a modeling compound impression. Fig. 749.

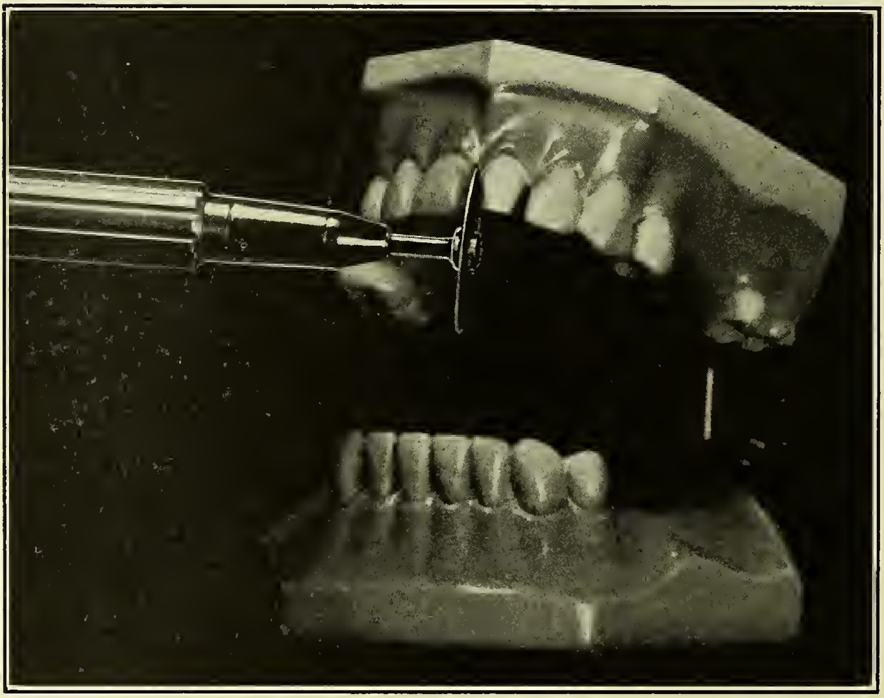


Fig. 751.—Shoulder is started on proximal surface with safe sided disc and carried around as far as possible to the lingual and labial angles. This shoulder is not at this time carried under the gum margin.

8. Up to this stage of the operation no attempt has been made to remove any tooth structure under the marginal gingiva or to prepare a shoulder in that area. Two seamless copper bands are now selected of proper size, annealed, fitted and festooned to extend under the marginal gingiva approximately 1 millimeter. These are marked with an x on the labial side and then laid aside to be used for taking modeling compound impressions later. Fig. 750. These bands are fitted at this time on account of the difficulty of doing so after the shoulder is prepared.

9. Now the preparation of the gingival seat or shoulder, on which the finished crown is to rest is begun. With a safe-sided carborundum disk, begin the cutting of the shoulder on the mesial and distal sides, and, by inclining the disk, bring the shoulder around as far as possible on to the labial and lingual surfaces. No attempt at this time should be made to extend the shoulder under the gingiva. Also, care should be observed to avoid cutting too deeply toward the pulp or making the shoulder too wide. If this is done, pulp exposure may result or the shoulder may be cut so wide that extensive cutting of the labial, lingual and proximal surfaces will be necessitated, to admit withdrawal of an impression and fitting of the crown. Fig. 751.

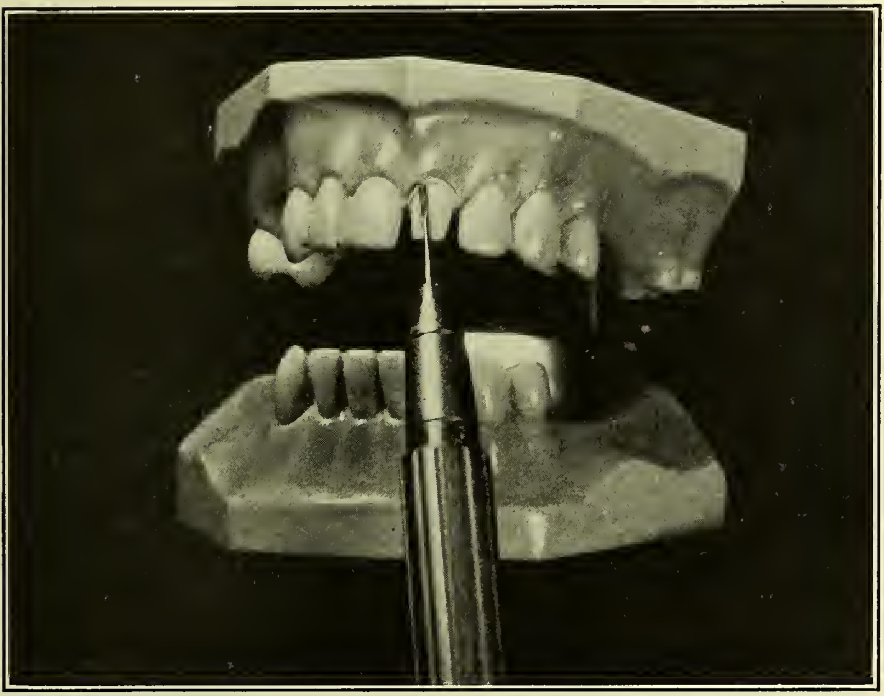


Fig. 752.—Shoulder being cut on labial surface, not under the gingiva yet, with 557 bur.

10. Now with fissure bur 557 begin the cutting of the shoulder on the labial surface, avoiding cutting it too wide or extending it under the gingiva. Fig. 752.

11. Next connect the shoulder cut on the labial surface with that previously cut with the disk on the proximal surfaces. For this purpose, use the fissure bur 557 and then with the same bur make the proximal part of the shoulder more definite in shape. Fig. 753.

12. Then, with Chayes stone number 34, cut the shoulder on the lingual surface and unite it with the proximal portions previously cut. Fig. 754. Avoid too deep cutting or extension under the gingiva.

13. The shoulder is next extended under the marginal gingiva on all surfaces, *following the curvature of the gingiva.* A shoulder following a straight line around the circumference of the neck of the tooth should be avoided, since this would necessitate deep cutting under the interdentinal papilla with resultant injury. With end cutting bur 957, 958 or 959, depending on the size of the tooth, begin on the labial surface and with its cutting end laid against the previously started shoulder, deepen it in the gingival direction until it enters approximately ½ millimeter under the gingiva. With the same bur, extend the shoulder in the same manner under the gingiva on the proximal surfaces and then on the lingual surface. Be careful not to make the shoulder too wide or to extend too deeply in the gingival direction, especially on the proximal surface, for the aforementioned reasons. Figs. 755 and 756.

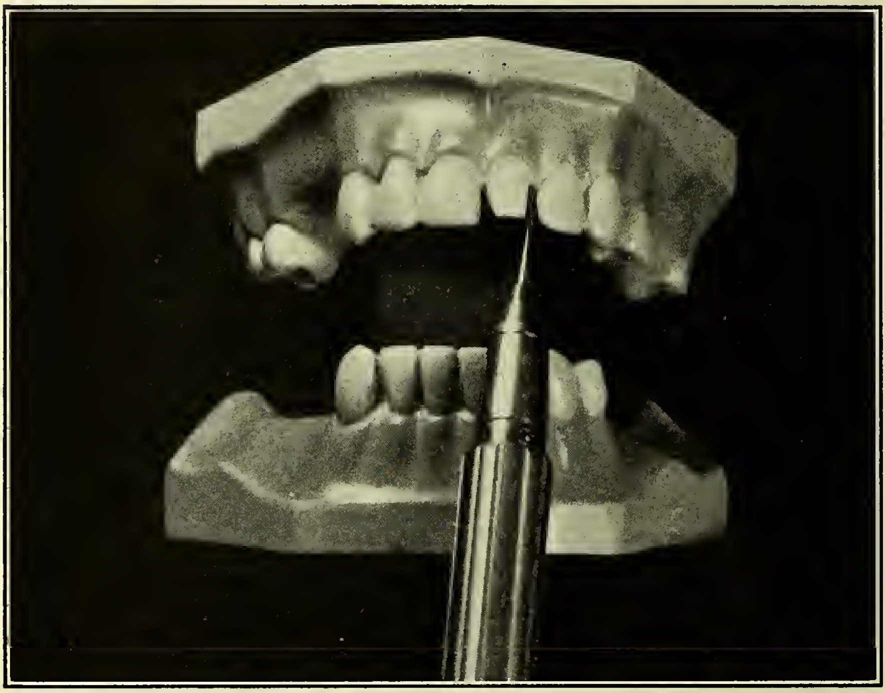


FIG. 753.—Connecting shoulder on proximal surface with that on labial surface and making proximal shoulder, previously cut with disc, more definite.

14. An examination of the shoulder at this time may reveal irregularities and roughness of outline, which must now be removed and its

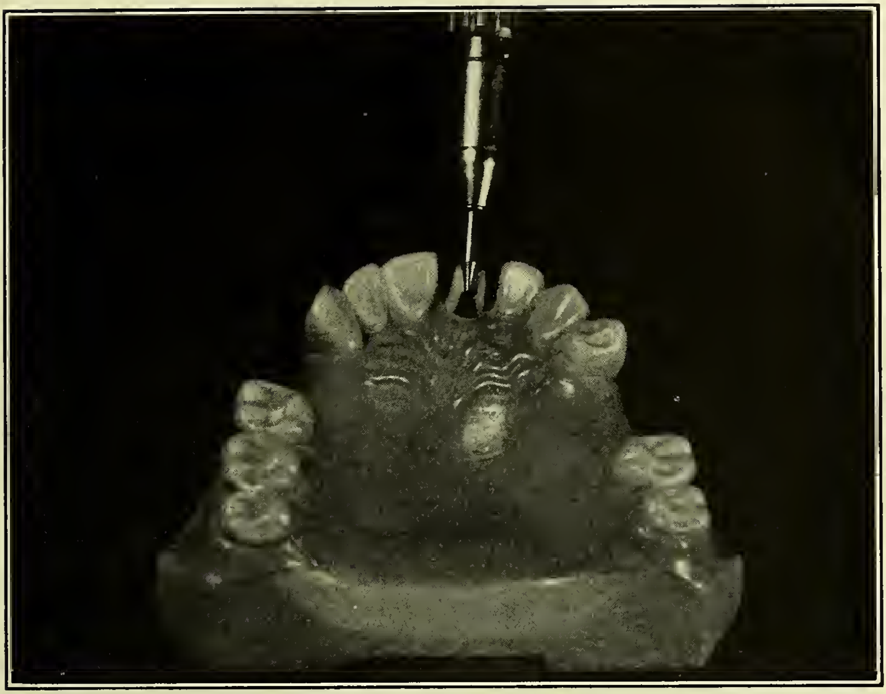


FIG. 754.—Starting shoulder on the lingual surface with No. 34 stone.

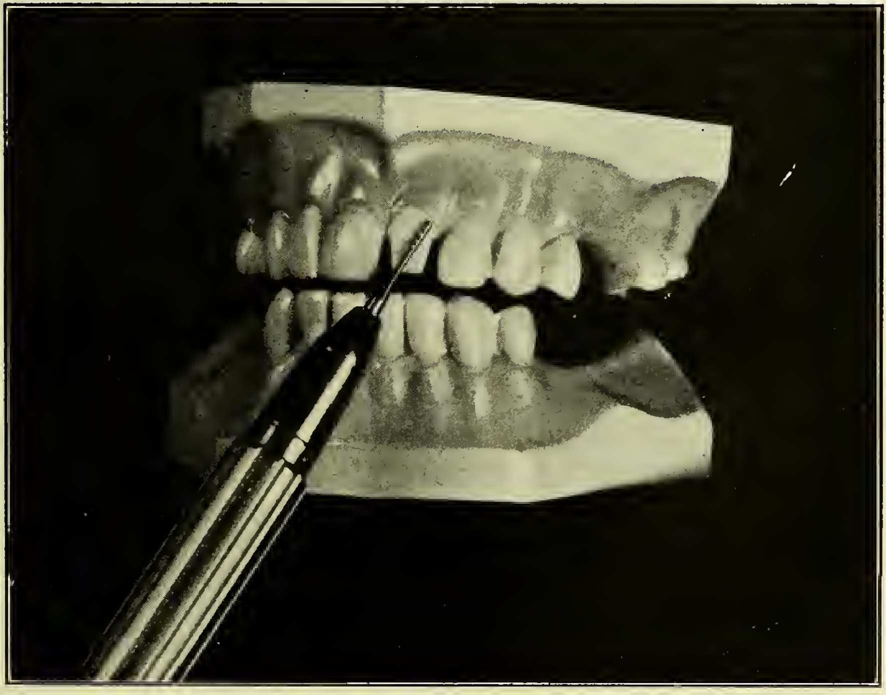


FIG. 755.—Extending shoulder under gingival margin with No. 957 end cutting bur. This is also done on proximal surfaces.

entire circumference smoothed and perfected. The number 3 inlay burs, which have previously been ground to one-half their length, and the ends left polished, one for straight and the other for right angle handpiece, are used for this purpose. With one in the straight handpiece, placed with its cutting blades against the shoulder, the labial and labio-proximal areas of the shoulder are smoothed. The lingual and linguo-proximal areas are perfected in the same manner with the bur in the right angle handpiece. Figs. 757 and 758. Instead of these instruments, end cutting burs of larger size, 958, 959 or 960 may sometimes be used.

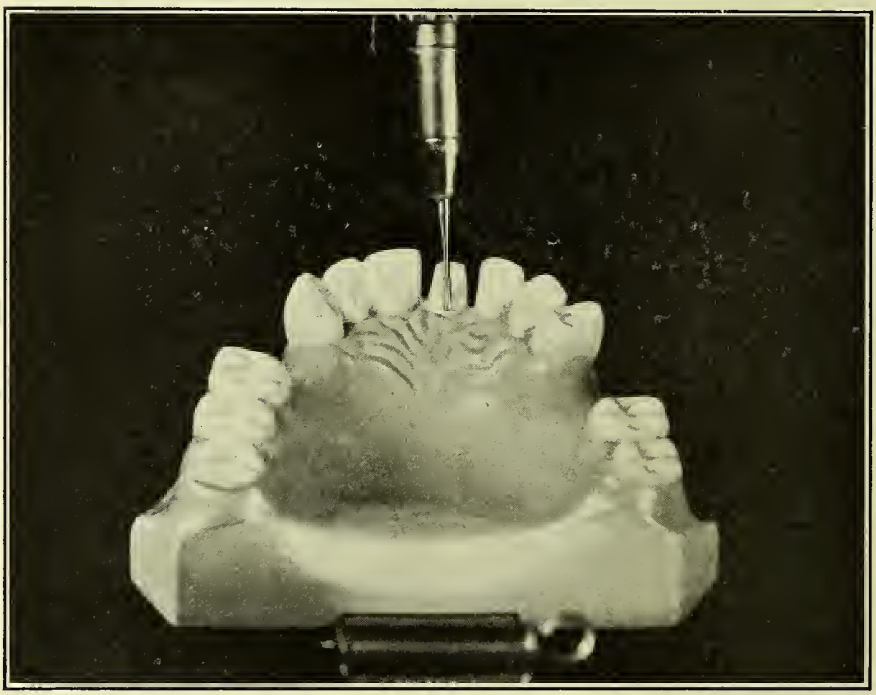


Fig. 756.—Carrying shoulder under gum margin on lingual surface. No. 957 end cutting bur.

The preparation is now complete and should present perfectly smooth axial surfaces, all of which slightly converge in the incisal direction, with no convexities which would interfere with the withdrawal of the impression or the carrying of the completed inlay to place. The gingival seat or shoulder should extend approximately 0.5 millimeters under the marginal gingiva, should be perfectly smooth and continuous, and should follow the general curvature of the gingival line. The convergence of all surfaces should not be too great, else the preparation will present too conical a form and the crown will not be well seated, having to depend too much on the cementing medium to hold it in place. This is especially true of the gingival third, which should be somewhat cylindrical in shape, so that the crown will be mechanically held in place to some extent by this form. Instead of the labial and lingual surfaces uniting in wedge shape, the incisal edge should be blunt and present a bevel over on to the lingual surface, in order to place the incisal seat at right angles to the stress brought on the crown in this locality by the teeth of the opposing jaw. A sufficient amount of the lingual and incisal surfaces should have been removed to give sufficient bulk of porcelain in the crown to resist stress. With a knowledge of the location and size of the pulp chamber obtained from a study of the roentgenogram, the grinding should not approach in too close proximity to it in any direction.

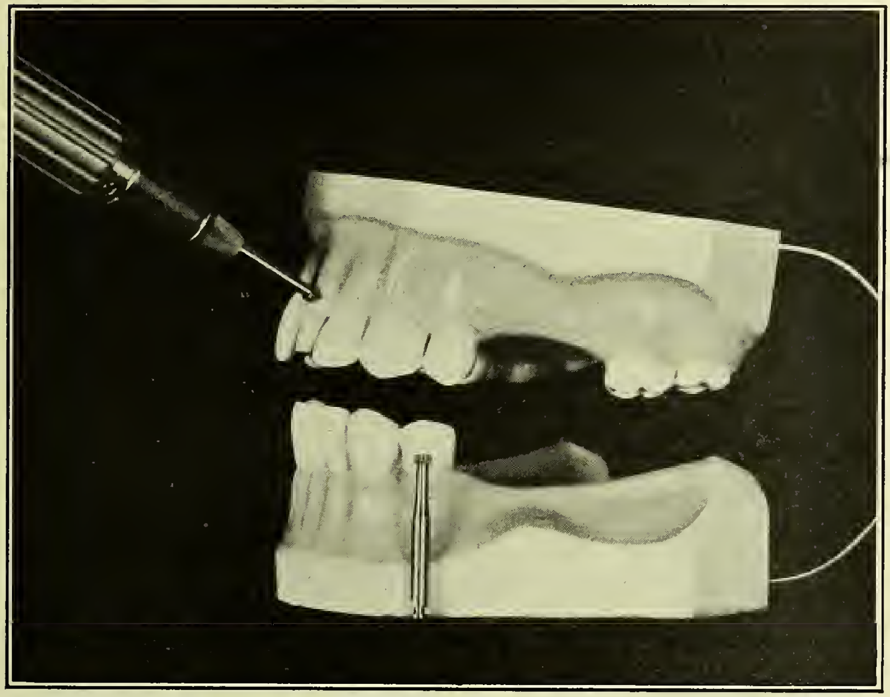


Fig. 757.—Showing use of S.S.W. inlay bur No. 3, which has been cut down to half its length, leaving the end smooth. The shoulder is thus made very clear-cut by removing the facets left by the other burs.

IMPRESSIONS, DIES AND MODELS

Two modeling compound impressions are now taken of the tooth in the annealed copper bands previously prepared. They should be filled with softened compound and carefully forced to place so that their festooned edges do not impinge at any point against the gingival shoulder, but perfectly encircle it. When chilled, the impressions, on withdrawal, should clearly show the perfect outline of the shoulder and should not appear distorted. Fig. 759 shows one of the impressions completed, and the other in position. With the latter band and impression still in position on the tooth, a plaster impression is now taken of it and two or more approximating teeth. This is now withdrawn, bringing away the copper band and modeling compound impression in position and in its proper relationship to the other teeth in the plaster impression. Now, a modeling compound impression is taken of the opposing teeth, and a wax bite is obtained. The copper band containing the compound impression of the prepared tooth imbedded in the plaster impression, the extra band and compound impression, the compound impression of the opposing teeth, and the wax bite are seen in figure 760.

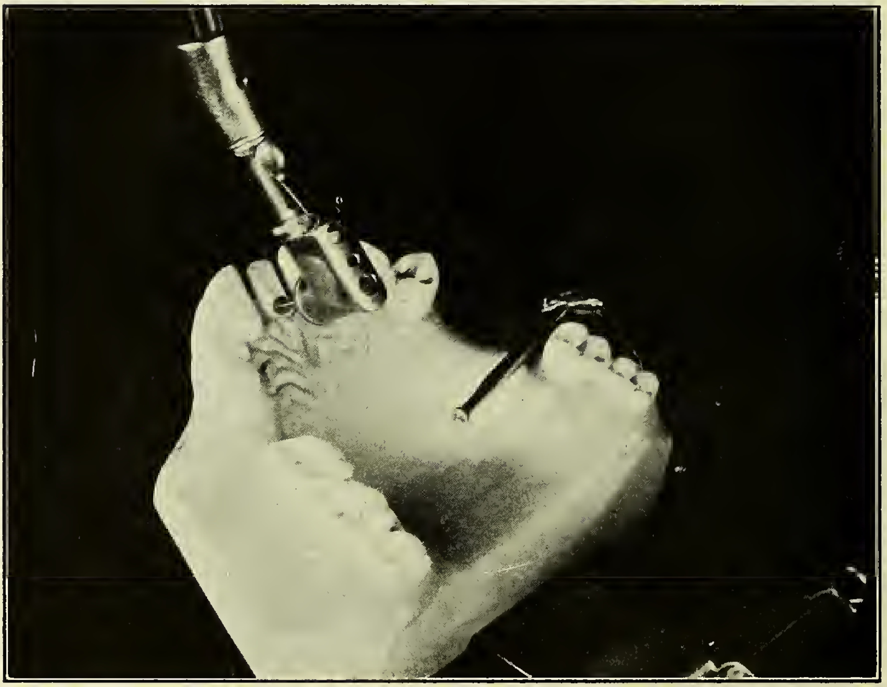


Fig. 758.—Same bur No. 3 used on the lingual surface with a contra-angle.

After taking the shade with a shade guide, the prepared tooth should be covered in such a manner that it will be protected from saliva and air. to prevent hypersensitivity, and so that the patient may not be subjected to embarassment from the exposure of the incomplete work to view. Provision must also be made to prevent the gingival tissue from shrinking over and obscuring the shoulder.

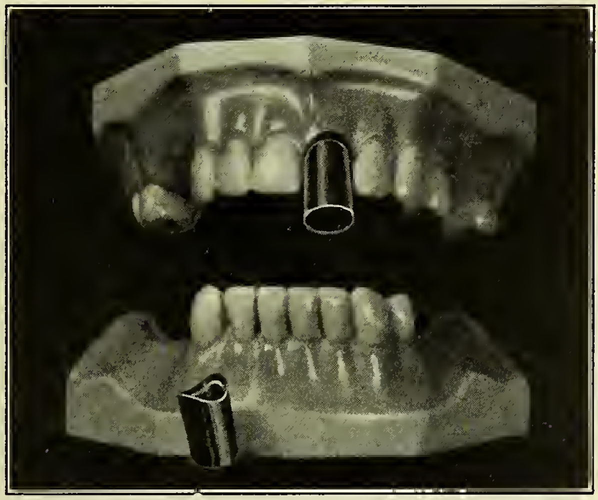


Fig. 759.—Two compound impressions are taken in bands previously fitted. One is seen left in position on the preparation.

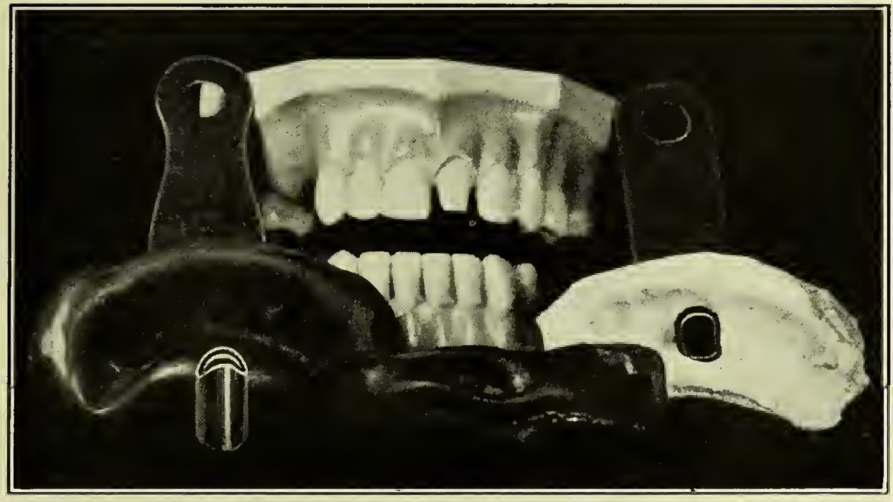


Fig. 760.—Plaster impression taken with band in place. Compound impression of lower teeth and wax bite. Extra compound impression in band is also seen.

For this purpose a celluloid crown form should be trimmed and fitted to the tooth, so as to extend slightly under the gingiva and not interfere with the occlusion. The inner surface of its gingival portion is swabbed with cavity varnish and then smeared with a thin coat of well softened guttapercha. This is then forced to place on the tooth and held in place until the guttapercha hardens, when it is withdrawn. Now a small hole is punched in both angles of the celluloid tooth form, it is filled with a mix of silicate cement of proper shade and carried to place. After setting of the cement and removal of excess, the patient is dismissed until the next sitting. This makes a very presentable temporary crown, protects the tooth from external irritants, and temporarily forces the gum away from the shoulder. It should not be left in position too long, on account of the danger of irritation and permanent injury to the soft tissues.

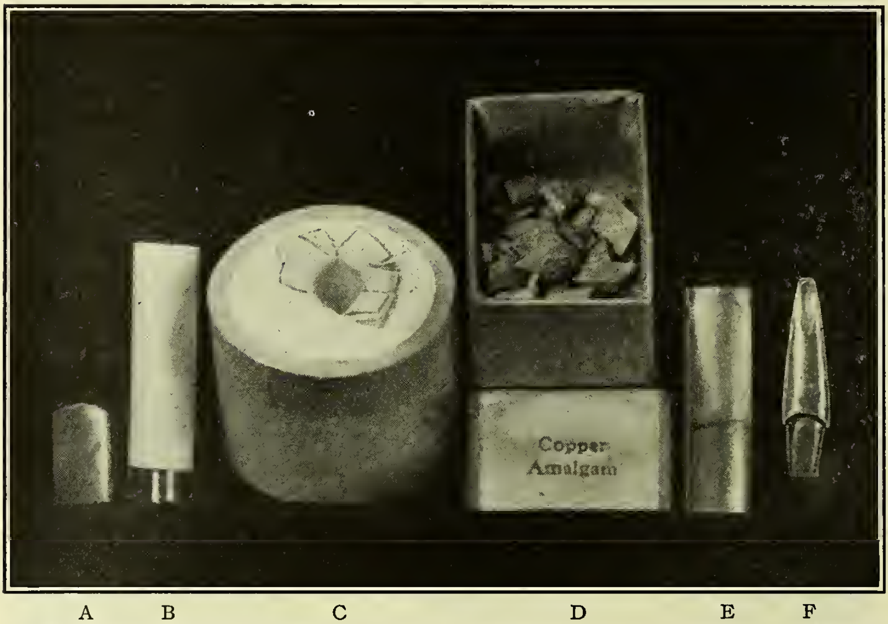


Fig. 761.—A, Band impression; B, band impression wrapped in paper; C, invested in rubber ring; D, copper amalgam, which is packed in invested band impression; E, die before removing impression and after plaster is broken away; F, die trimmed.

The next step in the technic is similar to that described for obtaining the die for the indirect method in gold inlay construction. The first modeling compound band impression previously taken of the tooth is now wrapped with paper, which is extended well beyond its impression end. It is then invested in plaster in a rubber ring, with its impression side facing up, and amalgam packed in to form a die. A good silver-tin or copper amalgam may be used for this purpose. Some dentists prefer Kryptex cement. As soon as set, the rubber ring, paper and plaster are removed and the amalgam die with the copper band are separated, the root end of the die cut down with a stone or file, made conical in shape and smooth. The consecutive steps of this operation are shown in figure 761. The die is now placed in position in the plaster impression previously taken, containing the second copper band and modeling compound, as illustrated in figure 762. Plaster models are now poured and mounted in the usual way on an articulator, which, when completed, carry the amalgam die in proper position. See figure 763.

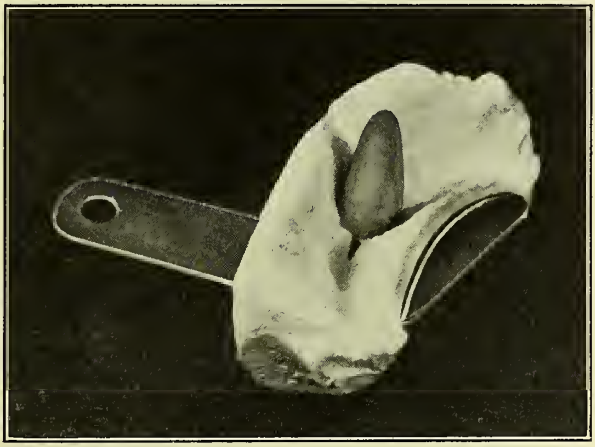


FIG. 762.—Die placed in position in impression.

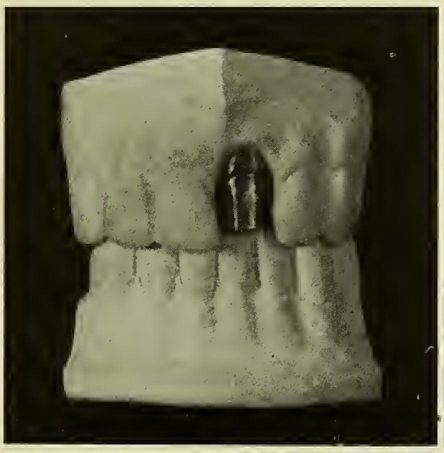


FIG. 763.—Models poured and articulated, with die in position on cast.

MAKING THE MATRIX

The various steps followed in making the matrix are so well illustrated in figures 764 to 773 inclusive that extended description of the procedures is superfluous. Platinum foil .001 is cut in triangular shape and large enough so that, when wrapped and fitted to the die, there

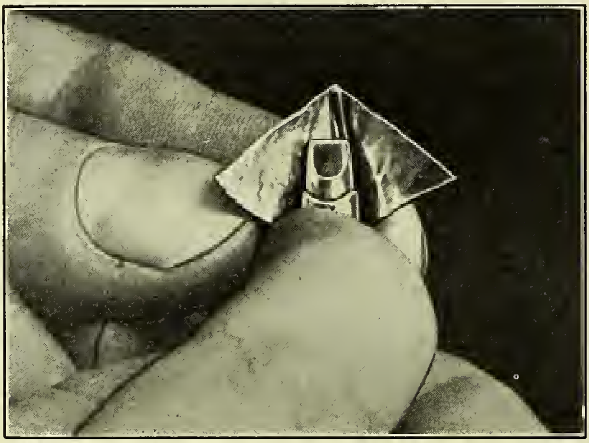


Fig. 764.—Die placed on piece of platinum foil so that there is sufficient to lap over incisal edge and make joint on lingual side. Pressed firmly against labial and proximal surfaces with thumb and index finger.

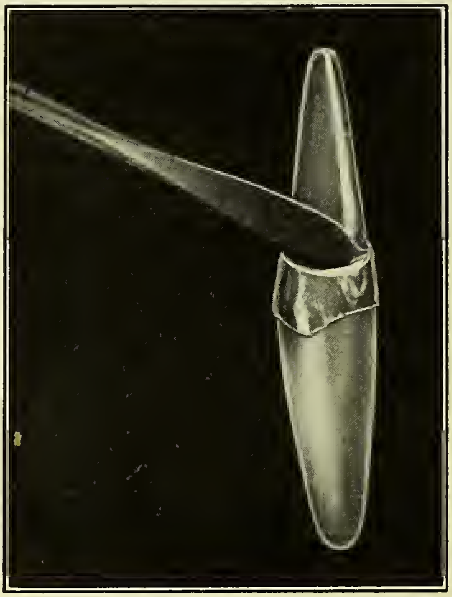


Fig. 765.—Labial view; burnished labial and proximal surfaces.

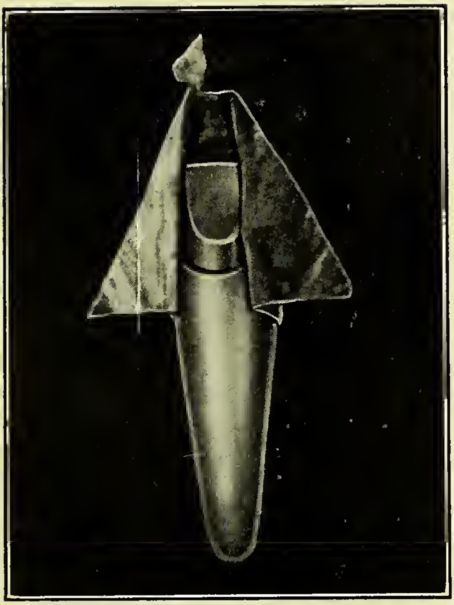


FIG. 766.—Cut straight across top, leaving enough to lap over on lingual surface 4 mm. from incisal edge.

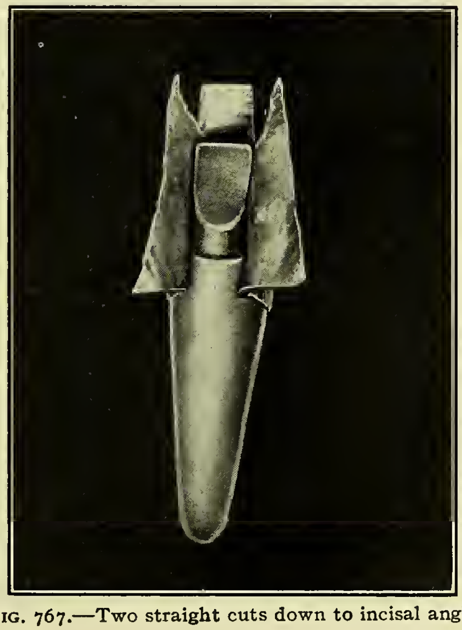


FIG. 767.—Two straight cuts down to incisal angles.

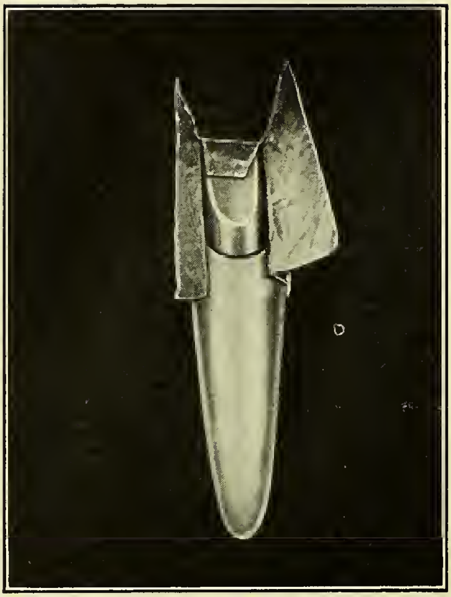


Fig. 768.—Burnishing down piece over incisal edge on lingual side.

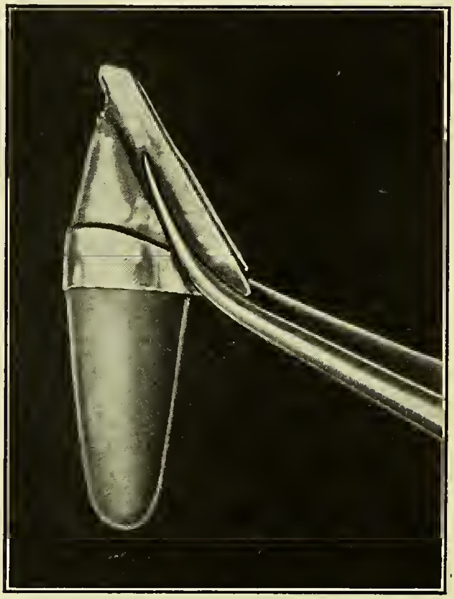


Fig. 769.—Bringing together both ends in centre of lingual surface.

will be sufficient excess to overlap the incisal edge and make a joint on the lingual surface. After thorough annealing in the furnace, this is placed against the labial surface of the die and pressed firmly against it and the proximal surfaces with the thumb and forefinger of the left hand. Fig. 764. It is then burnished with a flat bladed burnisher, number 2, 3, 4, or 34, tightly to the labial and proximal surfaces and against the shoulder showing on the die, (Fig. 765), when its lateral sides are bent back and the incisal portion is cut off with scissors about 4 millimeters above the incisal edge of the die. Fig. 766. Now make two cuts with the scissors to the incisal angles of the die as seen in Fig. 767 and then turn the intervening lap of foil down over the incisal edge of the die and burnish to place as shown in Fig. 768. Then with a pair of dressing pliers number 11 or 17, bring the lateral wings of the foil tightly together in the center of the lingual surface, as seen in Fig. 769 and cut off the excess, leaving about 2 millimeters to form a tinner's joint. See Fig. 770. Now, with the pliers, bring the two halves closely together, and lap them over a width of about 1 millimeter to form the first lap of the tinner's joint (Fig. 771), when the entire apron is then burnished down closely to the die, completing the joint. Now the excess platinum extending along the edge of the die is cut off. Fig. 772. Next cut off

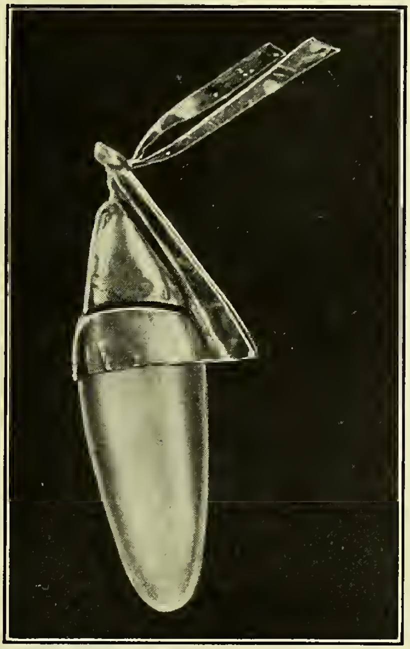


Fig. 770.—Cutting off excess, leaving 2 mm. for tinner's joint.

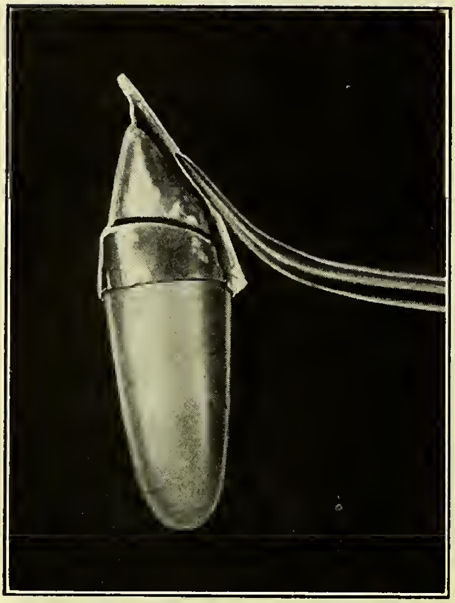


FIG. 771.—First lap in forming joint.

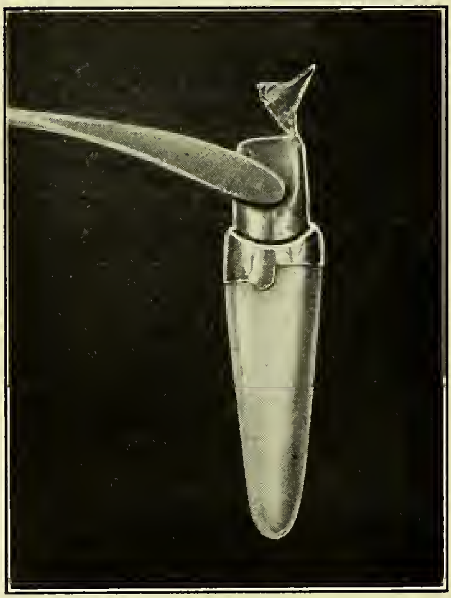


FIG. 772.—Burnishing over joint and cutting off excess at incisal edge.

any excess of platinum foil at the gingival portion, re-anneal and burnish the entire matrix to a perfect fit at the gingival shoulder and all other portions. Swaging may be resorted to in special cases, if needed, to perfect the fit. Now with a small stone grind off the excess thickness of foil at the tinner's joint on the shoulder, else the finished crown will not fit at this point. The matrix may now be removed from the die to see if it will stand up. If so it is complete in every detail and is ready for fusing of the porcelain. Fig. 773. In making matrices for inlays or crowns, it is important to remove stiffness or springiness, whenever it appears, by annealing.

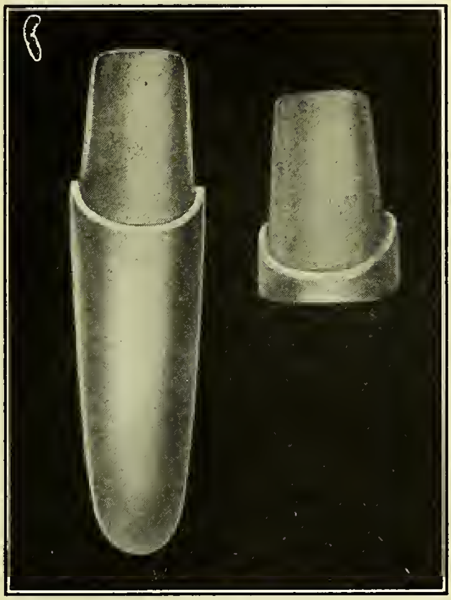


Fig. 773.—After reburnishing and trimming apron so that matrix will stand up. The die and completed matrix are seen.

BUILDING UP AND FUSING THE CROWN

The instruments and accessories for manipulation of the porcelain consist of the following:

Dappen dishes of different colors or cement slabs, for mixing porcelain;
Cement spatula or artist's palette knife for mixing;
Medicine dropper or syringe for distilled water;
Inlay carver, Lecron, Frahm or Vehe;
Camel or sable hair duster brush No. 1 for "whipping;"
Camel hair brushes, small, medium and large, long handles, for applying porcelain (Fig. 774);

Furnace pliers for introduction to and removal of work from the furnace;

College pliers No. 11, Imperialite;

Ball and inlay pliers;

Matrix tweezers;

Burnishers No. 60, 2, 3, 4, 33, 34, S.S.W.

With the Formula Selector (see Fig. 734) the formula of porcelain colors is determined for the gingival and incisal portions. As will be noted, the Formula Selector may be used in combination with the S. S. White, Twentieth Century, or the Justi tooth Shade Guide, and indicates the exact proportions of the S.S.W. porcelain shades to be used. With the measuring device or proportioner supplied with the porcelain bodies, the necessary proportions of each powder are placed in Dappen dishes of different colors, one combination for the foundation and gingival third colors and another for the incisal colors. These are now mixed with distilled water by the saturation lubrication method, as previously described. After allowing to stand for two minutes, the excess water is poured off and the case is ready for application of the porcelain.

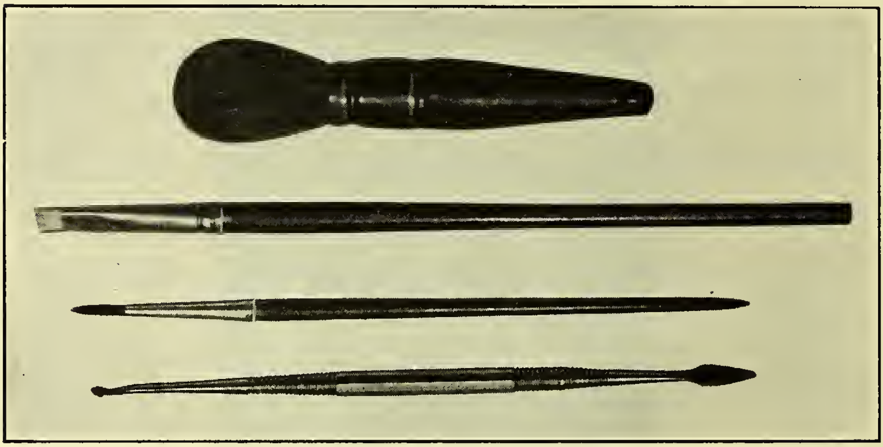


Fig. 774.—Duster brush No. 1, small brush for removing excess porcelain body at gingival, camel hair brush and inlay carver.

With the matrix securely placed on the die and its gingival portion perfectly adapted to the shoulder, it is coated with a layer of the foundation or gingival colors. This layer is applied with a small camel hair brush and is placed all over the matrix of a thickness to correspond to that of the shoulder. After being placed, the excess moisture should be removed with blotting or bibulous paper, a small absorbent napkin, small plaster of paris pencils made and shaped for this purpose, by whipping with a large camel hair duster brush number 1, or by dipping in a special portion of dry porcelain powder placed on a glass slab for that purpose. Carefully whipping it with the duster brush has a tendency to remove excess moisture and also to condense the porcelain into a closer mass, which is desirable. By dipping the mass in dry porcelain powder and then whipping it with the duster brush, excellent results are obtained. After dipping and whipping it once, if excess moisture still remains, the porcelain powder may be applied to one side only, which will have a tendency to draw the moisture to that side by capillary attraction, when it will be absorbed by the powder placed there. The powder added in this method does not cling to the mass previously placed on the matrix, consequently, exact shades are not necessary. Old powder, previously used and which has not been returned to the main bottle, may be reserved for this purpose. After applying, it is dusted off with the duster brush and carries away with it the excess moisture. In using the duster brush care should be used to avoid whipping off angles and fine detail of the soft body being laid on. In all cases, condensation of each layer placed is important. This may be accomplished by whipping as described, by agitation of the mass, or by burnishing. Agitation is accomplished by drawing the rough handle of the porcelain carver over the base of the model. Agitation for porcelain inlay work is accomplished in a similar manner by drawing the rough handle of the carver over the pliers holding the inlay matrix. Condensation and shaping may also be accomplished at various stages by molding with the dry clean thumb or fingers.

After application, drying and condensation of the first coat, it is placed in the furnace and fused to a biscuit bake, by gradually carrying the thermostat approximately 100°F. below the fusing point of the porcelain. On removal, it is allowed to cool, when shrinkage may have disturbed the adaptation of the matrix at the shoulder. This should be corrected, if present, by careful burnishing on the die, when the case is ready for the second application of porcelain. The gingival color is first applied and tapered toward the incisal. The first layer of incisal color is then applied, lapping it over the second layer of gingival color in the middle third of the matrix. Moisture is now removed, condensation is accomplished as with the first layer, the case is dried, placed in the furnace and fused to a high biscuit bake, about sixty degrees below the fusing point, but still short of a full glaze. On completion, the third application is then made, building the gingival portion out to full contour and placing on the second incisal portion to restore full length, incisal angles, contact points and contour. The second incisal portion is again lapped over the third layer of gingival portion at the middle third when, after removal of moisture, condensation, carving and drying, the case is placed in the furnace and again baked slightly below a full glaze. The method of handling the furnace and regulating the time and fusing temperatures was described in the section on porcelain inlays and is adaptable to jacket crown work. During the baking process, care should be taken to maintain the perfect adaptation of the matrix to the die by repeated trials and burnishing to the shoulder, if necessary. The apron of platinum extending from the shoulder over the "root" of the matrix should be kept free of porcelain, by removing with the brush any soft porcelain which runs on to it during application. Dies for anterior teeth, bicuspids and molars are seen in figures 775, 776, 777 and 778.

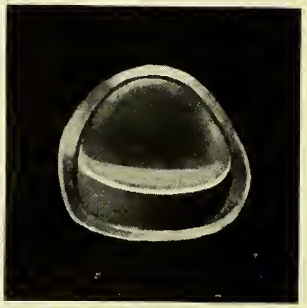


FIG. 775.—Die for lateral incisor.

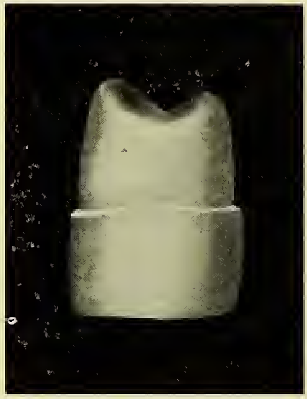


FIG. 776.—Die for a bicuspid tooth.

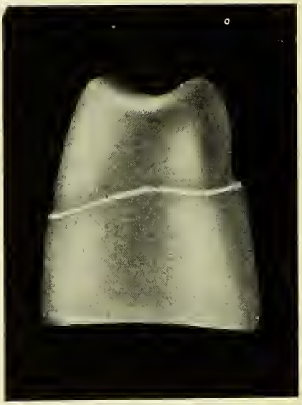


FIG. 777.—Die for a molar.

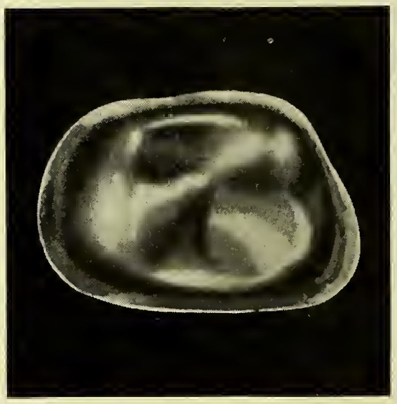


FIG. 778.—Die for a molar.

The excess platinum apron is now cut away, and the case tried in the mouth. Slightchanges in form and size may now be effected by grinding with a new, smooth, dry carborundum stone, if necessary. Do not use wet stones, on account of the danger of contaminating the porcelain with wet carborundum powder. Also avoid the heat incident to too much friction from too rapid grinding. Remove the powder incident to grinding with the chip blower or compressed air. The fit at the gingival shoulder should be tested with an explorer. If excess is found at any point, it should be ground off until the shoulder and gingival contour are perfected. Additional porcelain may now be added to perfect contour, contact points, shading, pathologic markings, and similar points, when, if this has been necessary, the case is again placed into the furnace and brought to a full glaze. The use of stains and glazes for these latter purposes has already been mentioned and may be adopted here. A die and completed jacket crown are shown in Figs. 779 and 780.

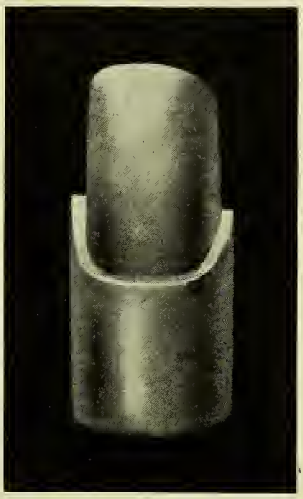


Fig. 779.—Die for a central incisor.

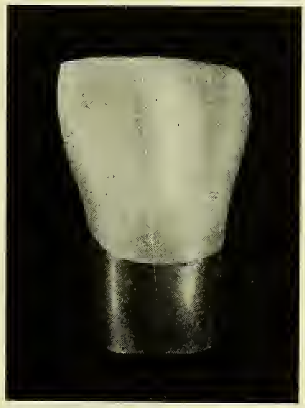


Fig. 780.—Completed jacket crown on die.

On completion, the platinum matrix is now removed by starting at the shoulder and gradually peeling it off, grasping it with a pair of matrix pliers for this purpose. A drop or two of water will facilitate its removal. On close examination, it will sometimes be found, after removal of the matrix that a thin film of porcelain marks the outline of the shoulder. This should be removed with a fine file or cuttle fish disk. The inner surface may now be etched with hydrofluoric acid or roughened with stones, if deemed necessary, the tooth dried, varnished and the crown cemented to place with a cement of proper shade.

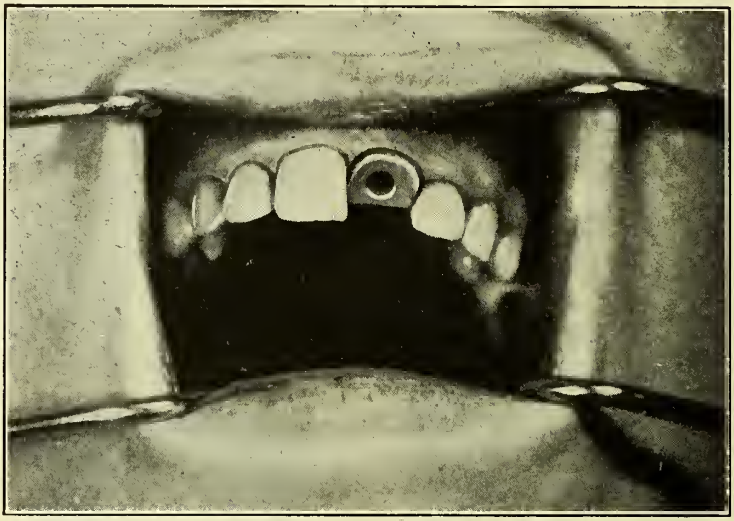


Fig. 781.—Root prepared for reception of post and gold core.

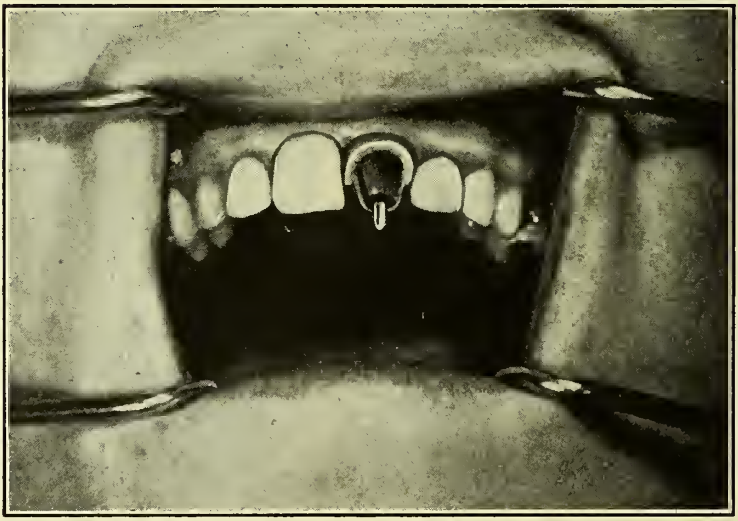


Fig. 782.—Post and wax model for core for case seen in Fig. 781, in position.

Gold Cores.—Figures 781, 782 and 783 show the method of constructing a gold core for a porcelain veneer crown on an incisor root. Figure 781 shows the root prepared for the gold core. In Fig. 782 is seen the wax model of the core built around a platino-iridium post extending into the root canal, and in position on the root. Figure 783 reveals the wax model after removal from the root. When cast in gold, the protruding, exposed end of the post is cut off, the core is cemented into place, trimmed and a porcelain jacket is constructed to fit.

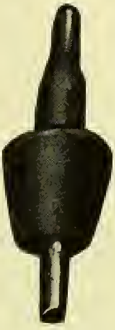


FIG. 783.—Post and wax model of case ready for investment and casting.

Bibliography

LeGro, A. L.: "Ceramics in Dentistry," 2nd ed., Dental Items of Interest Publishing Co., New York, 1920.

Avery. Hugh: Porcelain jacket crowns, Jour. Amer. Dent. Assoc., vol. XV, no. 4, April 1928, p. 601.

McBean, C. O. Porcelain as applied to dentistry, Jour. Amer. Dent. Assoc., vol. XIV, no. 1, Jan. 1927, p. 138.

Huff, Malvern D.: Porcelain inlays and substitutes, Jour. Amer. Dent. Assoc., vol. XV, no. 8, Aug. 1928, p. 1505.

Parker, C. G.: Porcelain jacket crowns, Ibid., p. 1578.

Klaffenbach, Arthur O.: Dental porcelain, glazes, stains, etc., Dental Cosmos, Dec. 1928.

CHAPTER XXIV

TREATMENT OF HYPERSENSITIVE DENTIN—EROSION—ABRASION—INTERPROXIMAL WEAR—SENILE DECAY

HYPERSENSITIVE DENTIN

Causes, Symptoms and Pathology.—It is conceded by all authorities that normal dentin, overlying a normal pulp, which has not been subjected to external sources of irritation through a loss of its protective covering, is not sensitive. The dentinal fibrillae are usually protected from external irritating agencies by the enamel and cementum. Through the action of caries, erosion, abrasion, cracks and fractures of the enamel, the careless use of scalers, or as the result of recessions of the gingivae, they become exposed to changes of temperature, as well as to the action of salt, sweet and acid substances. As a result, they become irritated,

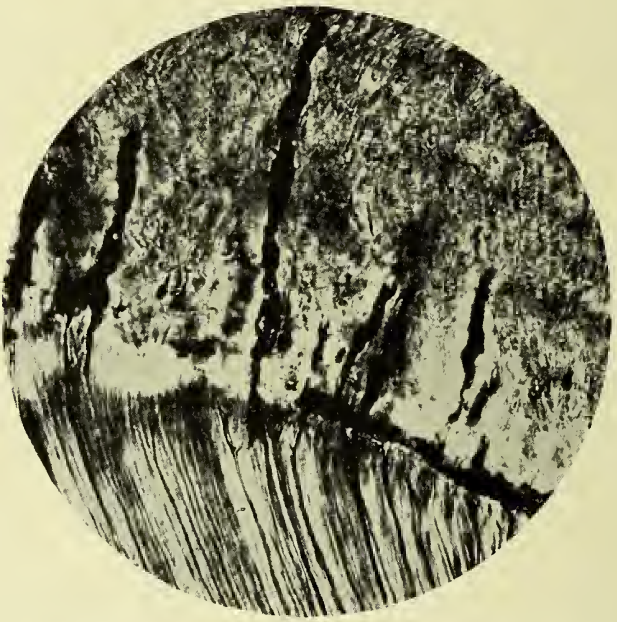


Fig. 784.—Enamel spindles extending from the dentin below, through the dentino-enamel junction into the first formed layers of enamel above. (Courtesy of Dr. A. Hopewell-Smith and "Dental Cosmos.")

and transmit these sensations in an exalted degree to the pulp, which becomes more responsive to the stimuli. Consequently, the dentin becomes abnormally sensitive to touch, or to the action of cutting instruments, and in some cases, even in the absence of dental ministrations, exhibits painful symptoms, definitely localized or reflected to other localities. In cases of fracture, hypersensitivity will usually manifest itself within twenty-four hours. In caries and other conditions of slow progression, its appearance is often much delayed. Figs. 784 and 785.

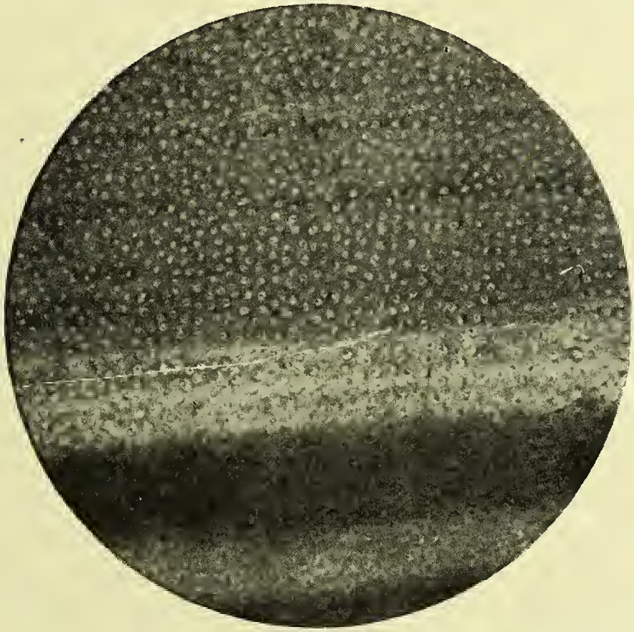


FIG. 785.—Low power picture of dentinal tubules. Note the small black dots in center of tubules (Tomes' fibres) and the surrounding white area (lymph?). (Courtesy of Dr. John B. Stein.)

Sensitive or hypersensitive dentin may be now defined as excessive or over-sensitiveness of this tissue. It is abnormal sensitiveness of an exposed area of dentin, exhibiting itself in the form of reflex or localized pains, sometimes in the absence of apparent external sources of irritation, or otherwise as a result of the contact of heat and cold, salt, sweet and acid substances, or of foods and instruments. In hypersensitive dentin the pain is not continuous, but is felt only as long as the irritant is present. On being touched with an instrument, the pain manifests itself definitely in the area touched; otherwise, its location may be difficult to determine.

Various theories have been proposed to account for the mode of transmission of sensation in the dentin. One group, including Morgenstern, Roemer, Howard Mummery, Chas. F. Bödecker and Tojoda, claims the presence of nerve fibres in the dentinal tubules as responsible. Another group, including Hopewell-Smith, Retzius, Koelliker, Tomes, Gysi, Prinz and others, disputes their existence and attributes the transmission of sensation to the action of the dentinal fibrils and lymph content of the tubules. According to Herman Prinz[1] the exalted transmission of sensation in cases of hypersensitivity is due to exposure of the terminal endings of the dentinal tubules to the fluids of the mouth. Following the exposure of the colloidal tubular contents, the surface tension within the tubules becomes exalted (hypertension), thereby producing an increase in the internal pressure of the colloidal solution in the tubules. As a result, the tubular contents become overdistended and exert increased pressure upon the underlying odontoblastic cells, which are in close relationship with the nerve filaments of the pulp. For these reasons, the sensations are transmitted in an exalted degree to the pulpal terminal nerve endings, and through them finally via the usual avenues to the receptive centers in the brain.

TREATMENT OF HYPERSENSITIVE DENTIN

Routine Procedures.—As routine procedures in handling ordinary cases of moderate hypersensitivity, the following measures may be adopted with great benefit:

First.—Use tact, encourage the patient, stimulate confidence in your ability, and adopt a calm, cheerful, sympathetic manner. The power of suggestion is valuable, deflecting the thoughts of the patient into other channels.

Second.—If a series of operations is required, select the simpler and less painful cases first, gradually leading up to the difficult ones.

Third.—Use sharp instruments. Cut with light, but quick, sure and decisive movements. Cut in a direction away from the pulp, as far as possible. If burs are used, avoid production of heat from friction, by frequently withdrawing them for a second, during the cutting process.

Fourth.—Exclude moisture, through application of the rubber dam in cavity preparation.

There are four classes of remedies used in the treatment of hypersensitive dentin, viz.:

1. Physical agents.
2. Escharotics or caustics.

3. Local anodynes or local anesthetics.
4. General anodynes or anesthetics.

TREATMENT OF HYPERSENSITIVE DENTIN BY PHYSICAL AGENTS

Heat.—Dry heat is applied by the use of the heated bulb of the chip blower, or an electrically-heated blast of compressed air. The cavity may first be moistened with absolute alcohol, when the heat is applied until the cavity is thoroughly desiccated. Moist heat has been applied in the form of a continuous stream of warm water during the cutting operation. The Merriam apparatus was designed for this purpose, consisting of a water tank heated by gas, alcohol or electricity, and a small rubber tube connecting it with a nozzle attached to the engine hand-piece. This is not applicable to modern methods of cavity preparation, since exclusion of moisture is considered desirable or necessary wherever possible.

Cold.—Fill the cavity with dry cotton and spray with ether, or ethyl chlorid for a few moments. Then remove the cotton and direct the spray into the cavity until densensitized. This has been recommended by some, but it is a very painful and dangerous method. Its effect depends on the rapid volatilization of the liquid and production of an extreme degree of cold. The sudden shock to the pulp may produce later degeneration and death.

The Electric Current.—Formerly several appliances were available for application of the cataphoric current. The anode of the cataphoric apparatus was applied to the cavity, which was saturated with a cocaine or novocain hydrochlorid solution, while the cathode was placed in contact with the patient's body. The current was slowly and gradually increased, thus forcing the novocain solution into the dentin. The method has been largely abandoned, on account of slowness, frequent failure and tendency to production of pulp complications.

Treatment of Hypersensitivity by the Use of Caustics.—These agents prevent the transmission of sensation, by chemically destroying living tissue. They act by (1) abstracting water from the tissues; (2) by dissolution or precipitation of albumin; or (3) by oxidation or substitution. The agents used are zinc chlorid (deliquesced); absolute alcohol; trichloracetic acid, 10 to 15% solution; silver nitrate in pencil form, or in solutions of from 10 to 50% strength, or deposited after the Howe method; and Robinson's remedy (caustic potash and phenol, equal parts in enough glycerin to make a paste). Zinc chlorid is very irritating and should not be used in close proximity to the pulp, while silver nitrate, owing to its discoloring properties, should be used cautiously on exposed surfaces. The action of sunlight greatly increases its efficacy. Irritation of the pulp also is likely to result from the use of the latter agent in deep-seated cavities. Fig. 786.

Since these agents are strongly caustic, they should be very carefully applied, to prevent spreading and coming in contact with the soft tissues and to avoid pulp irritation. A few crystals of zinc chlorid, trichloracetic acid or silver nitrate, placed on a glass slab or in a Dappen glass, dissolved in a small amount of water, applied to the dried and desiccated cavity or sensitive neck of a tooth and heated with warm air for several minutes will usually be of great assistance. Absolute alcohol applied on a small pledget of cotton and evaporated to dryness is also effective. Where cutting is to be done, the application of one or the other of these remedies, in conjunction with the intelligent use of *sharp* instruments and a manner designed to secure the confidence and cooperation of the patient is usually an effective method for emergency cases. If necessary, several applications at intervals during the cutting may be made. For relief of sensitivity about the necks of teeth with receded gingival tissues, the area may be isolated with absorbents, dried, desiccated with hot air, the remedy

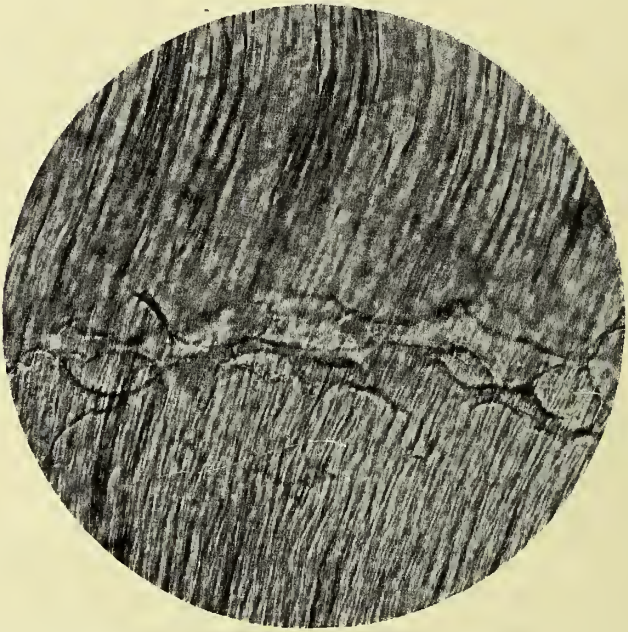


Fig. 786.—Interglobular spaces in the dentin of the crown of a tooth. (Courtesy of Dr. John B. Stein.)

applied in small amounts to keep it away from the gingival tissues, and evaporated to dryness with heat from the chip blower or hot air syringe. Following this treatment, the area should be thoroughly sprayed with warm water to remove any traces of the remedy and prevent its contact with the soft tissues. Silver nitrate is contra-indicated on exposed surfaces owing to its property of producing discoloration. For this reason its use as a desensitizing agent is quite limited, except in the deciduous teeth.

In transient or recurrent mild attacks of hypersensitivity at the necks of teeth, the anointing of the affected surfaces, after cleansing and before retiring at night, with milk of magnesia, and the regular use of an antacid dentifrice will be of assistance in reducing the condition.

Local Anodynes or Anesthetics.—Cocain hydrochlorid, novocain hydrochlorid or procaine, menthol, oil of cloves, eugenol, phenol, ethyl chlorid, ether and chloroform have all been used for treatment of hypersensitive conditions about the teeth. Novocain and Cocain have been used for this purpose after one of the following methods, viz.:

1. Seal into the cavity for a few days a creamy paste of cocain hydrochlorid in vaseline or phenol; or in the form of oleate of cocain.

2. Apply locally and evaporate to dryness the following prescription of J. P. Buckley.

℞.	Cocainae hydrochloridi..........	gr. XX (1.25 Gm.)
	Chloroformi....................	ʒ II (8.00 cc.)
	Etheris q.s.ad..................	℥ I (32.00 cc.)—misce.—(Buckley).

3. Force into the dentin, with a high-pressure syringe, a solution of cocain or novocain hydrochlorid.

4. Accomplish the same result with the same method as used in "pressure anesthesia," by means of unvulcanized rubber.

5. Apply novocain hydrochlorid by means of the cataphoric current.

6. Apply the same remedy by means of the infiltration, conductive or nerve blocking anesthesia method. The high pressure syringe and the cataphoric current are now largely abandoned.

Of these various procedures, the injection into the surrounding tissues of novocain or procaine, combined with adrenalin chlorid or epinephrin, either by the infiltration or nerve blocking method is the only one of any great value. Topical applications of these agents into the cavity accomplish very little. Infiltration or conductive anesthesia may be used in extreme cases, but is not successful unless the anesthesia is sufficiently deep to anesthetize the pulp. This requires an even more careful technique than that used in extraction operations, where, in many instances, the pericementum, gingival and bony tissues are anesthetized, but the pulp is not.

Formerly, these agents were injected directly into the pulp via the dentinal tubules with a heavy, "high-pressure" syringe specially designed for the purpose. A blunt-end hypodermic needle was inserted into a small pit drilled into the dentin, which the needle perfectly fitted, the plunger of the syringe carrying the solution forward under great pressure, through the tubules into the pulp. Owing to the fact that failures were many and inflammation and subsequent death of the pulp were frequent, the procedure has been abandoned. The now obsolete method of introducing solutions of this nature into the pulp by means of cataphoresis has already been mentioned. The difficulty of forcing novocain solutions into the pulp by the "pressure anesthesia" method has also largely militated against its use. A small pledget of cotton is saturated with a solution of novocain hydrochlorid and adrenalin or epinephrin, placed in the cavity and covered with soft unvulcanized rubber. Continuous pressure is brought to bear on the soft cushion of rubber with a large burnisher, effort being made to prevent backward flow of the solution and to force it into the dentinal tubules. The method, when carefully applied, will sometimes produce results, although it is usually more successful in anesthetizing the pulp for its removal, in cases of pulp exposure. The use of cocain in dentistry has largely been abandoned since the introduction of the less dangerous and more potent novocain and adrenalin combinations and the necessity for compliance with the Harrison Anti-narcotic bill.

Menthol, *Clove Oil*, *Eugenol* and *Phenol* as anodynes. Menthol may be substituted for cocain in the prescription of Buckley given above. Clove oil, eugenol or phenol may be applied on a pledget of cotton and evaporated to dryness, by means of hot air, repeating the procedure several times, if necessary, as the operation progresses. Clove oil or eugenol may be used alone or combined with phenol, equal parts, and used in the same manner, or sealed into the cavity for 24 hours, with occasional good results.

The Hartman Desensitizer.—On January 21st., 1936, Dr. Leroy L. Hartman, Professor of Dentistry, School of Dental and Oral Surgery, Columbia University presented at a joint meeting of the First and Second District Dental Societies of New York, his formula for a new desensitizing agent.

Dr. Hartman bases his claims for the action of this compound on the following theories: (1) that the dentin must contain lipoids which play an important part in the transmission of sensation in and through the dentin; (2) that ether and chloroform are both lipoid solvents and therefore will dissolve these lipoids when brought in contact with dentin containing them; (3) that thymol is soluble in lipoids and will be dissolved in the lipoids of the dentin when applied to them; (4) that the application of these three agents, prepared in a properly balanced solution, would produce a reversible action, viz., the ether and chloroform would dissolve the lipoids and the thymol would become dissolved in them; (5) thus causing dissolution of the lipoids concerned in the transmission of sensation and also an analgesic effect in the area of application, through action of the thymol. The validity of these theories has been disputed by Hill and others and upheld by others. Dr. Hartman stresses the importance of a properly balanced formula and a careful technic used according to his directions.

FORMULA OF HARTMAN DESENSITIZER BY WEIGHT

Thymol	1¼	parts
Ethyl Alcohol	1	part
Sulphuric Ether	2	parts

Keep tightly corked in a brown glass bottle. One-half ounce is sufficient for 200 applications. A fresh solution should be made up more frequently when the weather is warm and dry. Do not use rubber stoppers because they become dissolved. Glass stoppers become clogged with the thymol and will allow the ether to evaporate. Cork stoppers changed frequently are satisfactory. A stopper with a tin lining is preferable. The solution is now available in small glass ampuls.

DIRECTIONS FOR USE

It is preferable to use the rubber dam. If cotton-rolls are used, varnish the gums surrounding the tooth. Change the cotton-rolls immediately after the application. Wipe the saliva from the field of operation with a cotton pellet. A topical application is then made on a moistened—not saturated—pellet of cotton directly to the dentin or caries. The solution will not act through enamel. If applied over the caries, a second application may be necessary after the removal of the caries.

Keep the pellet in contact for 1 minute in children's teeth and 1½ minutes in adults' teeth. Remove the pellet and direct a blast of warm air to the area of application. Do not attempt to dehydrate the area. The depth of anesthesia is obtained about 2 minutes after the application. If the rubber dam is used the anesthesia will usually last over one hour's time. If only cotton rolls are used and the saliva is allowed to come in contact with the cavity, after the application of the anesthesia, the duration of anesthesia is reduced to about 20 minutes.

In making the application for crown preparations it is necessary to vary the technic to cut through the enamel in order to expose the dentin. The dentin should then be swabbed for about one-half minute. It will then be possible to continue with the cutting. Several applications may be necessary before completing the preparation.

For fitting bands and taking impressions of crown preparations, if the preparation is swabbed once or twice, allowing some of the solution to flow into the gingival crevice, the patient will not complain of any discomfort when the impression is taken.

Introduction of this dentin obtundent caused widespread publicity and resulted in many claims and counter-claims as to its efficacy. At this writing it is impossible to properly evaluate its usefulness, since it is in the experimental stage. Undoubtedly many failures reported in its use have been due to faulty technic or improperly prepared formulas. Careful operators have reported complete desensitisation in a fair percentage of cases and partial desensitisation in a larger number.

Treatment by General Anodynes or Anesthetics.—1. Administer internally potassium, sodium or ammonium bromid, xx to xxx gr. (1.25 to 2.0 gms.), half an hour before the operation.

2. Administer chloral hydrate x gr. (0.75 gms.), or ipral sodium 2 gr. (0.13 Gm.), half an hour before the operation.

3. In extreme cases morphin sulfate one-eighth gr. (.008 gms.), or codein sulfate one-quarter gr. (.016 gms.), may be resorted to. In handling extremely nervous or neurotic patients, the use of remedies of this nature may occasionally be resorted to for their psychologic, as well as systemic effect, in lowering the general nervous tension of the patient. However, a word of warning must be sounded against their indiscriminate use. The market is flooded with numerous proprietary remedies with various trade names, which are recommended indiscriminately by their manufacturers for the relief of pain in all kinds of dental and medical ailments. The danger of producing drug-forming habits through the use of these preparations cannot be too strongly emphasized. Some of these "cure alls" are dangerous and others are worthless.

4. Nitrous oxid in combination with oxygen is valuable in extreme cases, where all else has failed.

EROSION OF THE TEETH

By Erosion of the teeth is meant their chemical or chemico-mechanical wearing away in such a manner that broad, shallow, smooth, highly-polished excavations or depressions are made in the enamel and dentin, on surfaces not subject to mastication. Erosion usually is confined to the gingival third of the labial surfaces of the anterior teeth (Fig. 787), though it may involve the labial and buccal surfaces of the entire denture.

The condition is an entirely separate process, and exhibiting other appearances than those seen in caries. The causes are also of a totally different nature. No attempt will be made here to discuss, in detail, the etiology and pathology of the disturbance, that phase of the subject being out of the province of this work. Numerous ingenious theories have been presented from time to time, in an endeavor to explain the nature of this pathologic state. At present, it may be said that the origin of the clinical manifestations is not well understood. Many of the cases are not true erosion, but the result of abrasion from faulty or excessive brushing and the use of gritty dentifrices. The chief causes, as advanced by various writers may be briefly summarized as being supposedly due to a combination of mechanical and chemical factors.

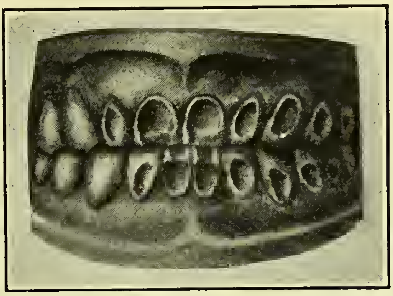


FIG. 787.—Marked case of erosion. (From G. V. Black's Operative Dentistry.)

CAUSES OF EROSION

Mechanical Factors.—The action of the muscles of the lips and cheeks, and of the tooth brush against the affected surfaces.

Chemical Factors.—1. Diseases of sub-oxidation or faulty metabolism, resulting in the excessive formation and elimination from the labial and buccal mucous glands of (*a*) acid sodium phosphate or (*b*) acid calcium phosphate, or both substances (Edward C. Kirk).[2]

2. Excess of lactic acid in the saliva, producing not the typical form, but a general erosion of all the teeth of the denture (Kirk).[3]

3. Excess of acid salts excreted from the blood by the salivary or mucous glands, or present in the saliva from fermentation processes (W. D. Miller).[4]

4. Excess of alkaline salts or bases present in the saliva (John A. Marshall).[5]

5. Solution of the organic matrix by bacterial enzymes and later dissolution of the inorganic material (Prieswerk).[6]

6. Excessive use of extraneous acids, such as lemon juice, vinegar, grapefruit, and grapes (Miller,[7] S. H. Guilford,[8] Tomes[9]).

7. Acid vapors from nitric and sulphuric acids, acting in the mouths of workers in factories, where these acids are largely used or manufactured (Miller[10]).

8. Acidity from a local acidosis in the peridental tissues, as a result of traumatic occlusion. (Paul R. Stillman and J. O. McCall.)[11]

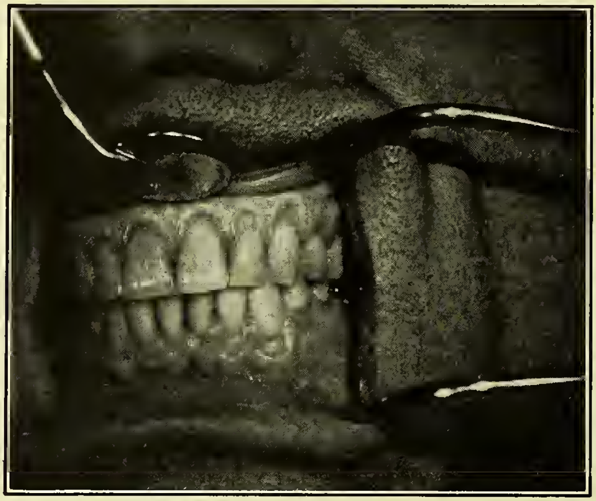


Fig. 788.—Gingival recession and abrasion due to improper tooth-brushing. (Courtesy of Dr. Isidor Hirschfeld and "Dental Items of Interest.")

Undoubtedly, many cases of pure tooth brush abrasion have been described and confused with erosion. On elimination of these and the unusual cases mentioned under headings 4 and 5, 6 and 7, it may be seen that the probable causes may be classified largely under the theories of Kirk, Stillman and McCall. This would lead us to the rational conclusion that the majority of the cases presenting today may be due to combinations of two or all three of the following factors, viz., (1) faulty methods of brushing or friction of the labial and buccal muscles; (2) traumatic occlusion and its attendant periodontoclasia; or (3) systemic disturbances the result of faulty metabolism. These are causative factors which, in the light of our present knowledge, can be accepted alike by the periodontists, pathologists and men and women in the operative field. Fig. 788.

As a rule, the progress of the affection is very slow. As a result of the mechanical factors mentioned, viz., either the toothbrush or the action of the muscles of the lips and cheeks, the affected surfaces usually are highly polished. They may be very shallow, saucer shaped, and involve only the enamel. Later, the dentin is affected. When the dentin becomes exposed, tubular calcification frequently occurs (resulting in solidification), and discoloration often is seen. Hypersensitivity may be marked, or in some cases almost absent. In some instances, caries involvement may occur and the characteristic manifestations be masked. Fig. 789.

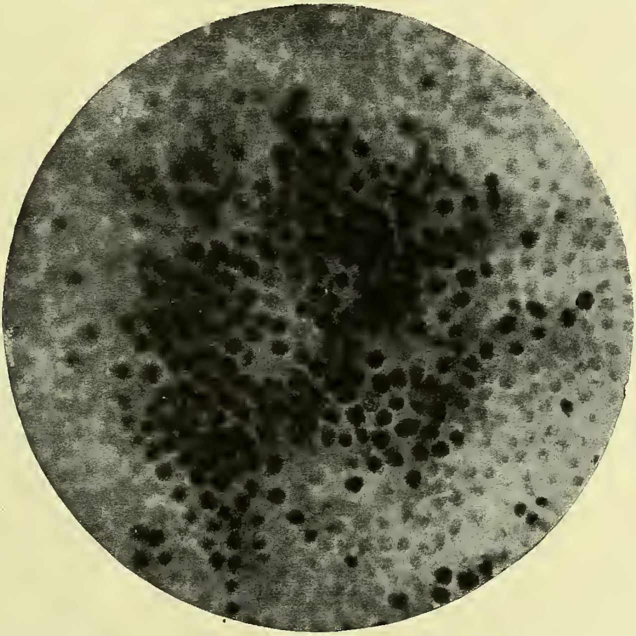


Fig. 789.—Dentinal tubules as seen from the pulp chamber. The tubules have been freed of organic matter and those appearing black are filled with air. High power. (Courtesy of Dr. John B. Stein.)

TREATMENT OF EROSION

The treatment of the condition may be both preventive and restorative in character.

Preventive Treatment.—Since constitutional disturbance is in many instances supposedly concerned in the condition, its prevention should, of necessity, be both general and local in character.

General Preventive Treatment.—The institution of treatment directed against faulty metabolism, including such features as regulation of the diet, exercise, fresh air, massage, Turkish baths, and the administration internally of sodium bicarbonate, ten to thirty grains (0.75 to 2.0 gms.), sodium chlorid, thirty to forty-five grains (2.0 to 3.0 gms.), or sodium phosphate, one drachm (4.0 gms.), three times a day, is of value. Plenty of pure water should be drunk; or as a substitute, lithia water, or lithium citrate, five gr. (0.25 gms.) in water, at meals.

Local Preventive Treatment.—This consists of the usual prophylactic and curative procedures advocated by prophylactic and periodontic specialists for the prevention and cure of periodontal disturbances, including relief of traumatic occlusion, proper use of the brush and the measures described in the Chapters on "Prevention." Robinson's remedy, zinc chlorid, milk of magnesia and other agents for relief of hypersensitivity are sometimes of value. Stiff tooth brushes and gritty dentifrices should be abandoned.

Restorative Treatment.—If the case has progressed far enough to necessitate operative interference, extend the cavity margins well beyond the eroded area and insert porcelain inlays, gold inlays or gold fillings. If cavities are not extended well beyond the eroded areas, recurrence often supervenes from a continuance of the erosion, unless the causes of the condition are removed.

ABRASION OF THE TEETH

General Characteristics.—By abrasion is meant the mechanical wearing away of the teeth. It occurs most frequently on incisal and occlusal surfaces. (Figs. 790, 791, 792 and 793.) It may also affect the contact points (interproximal wear); the labial or buccal surfaces (tooth-brush abrasion); as well as the labial, buccal and lingual surfaces, in cases of wear incident to excessive overbite, or as a result of the action of poorly fitted clasps and artificial dentures. Figs. 794, 795, 796 and 797. Abrasion may affect one or a few teeth, or the entire denture, depending on the nature of the cause. Abraded teeth often present exposed dentin, from wearing through of the enamel, tubular calcification and solidification, with a highly burnished appearance, badly stained and discolored areas, jagged and checked enamel borders, hypersensitiveness and secondary dentin formations. In some cases, hypersensitiveness may be intermittent in character, appearing and disappearing at occasional or frequently repeated periods. In others, secondary dentin formation may slowly increase in amount, produce gradual obliteration of the pulp chamber and canals, with slow degeneration, loss of sensitivity and death of the pulp. Fig. 798.

Causes of Abrasion.—The causes of the condition may be mentioned as follows:

1. Traumatic Occlusion. Figs. 799 to 802.

2. Habits, such as chewing tobacco or gum, the betel nut by natives of certain tropical countries, or tooth picks; excessive gritting of the teeth from nervousness and nerve irritations or lesions (Bruxomania); frequent use of a pipe in smoking. Figs. 803, 804 and 805.

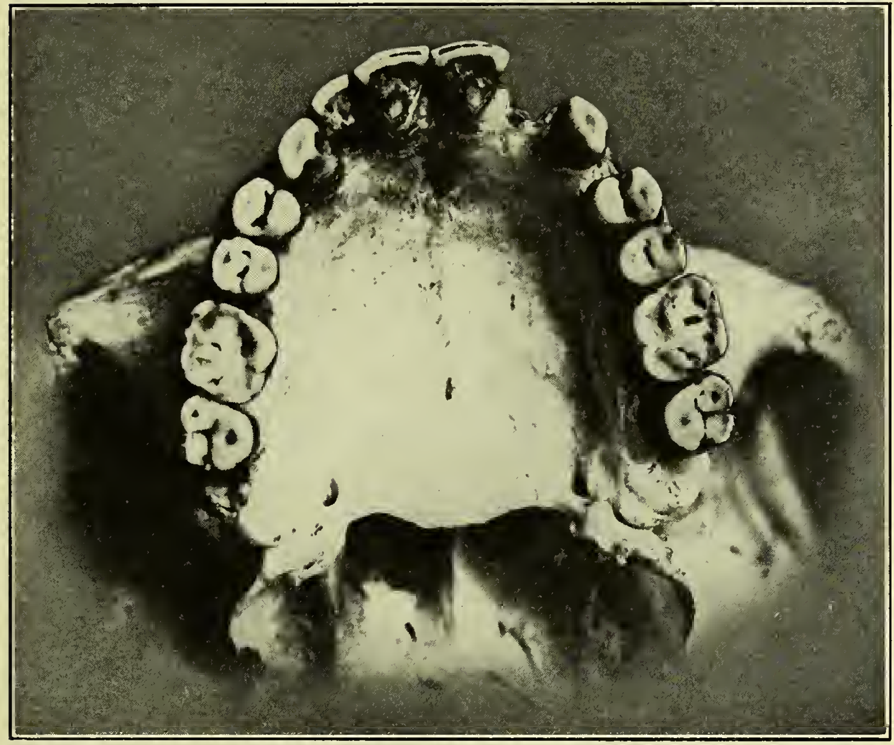


Fig. 790.—Abrasion of incisal and occlusal surfaces.

3. Ill-fitting dentures and clasps, producing constant wear on the affected surfaces.

4. Excessive mastication of coarse foods, seen among the Eskimos and other aborigines Figs. 806 and 807.

5. Excessive use of coarse bristle brushes and gritty dentifrices (tooth-brush abrasion).

6. Constant gliding of the contact points against each other during occlusion (interproximal wear).

Preventive Treatment of Abrasion.—Prevention of the condition consists in avoidance or correction of the causes which may lead to its production. Fig. 809.

1. Correct or avoid ill-fitting metal clasps and dentures.

2. Discontinue the habits of chewing tobacco, gum, the tooth pick and others of similar nature.

3. Avoid gritty dentifrices, coarse bristle tooth brushes, as well as excessive or improper use of brushes and dentifrices of all kinds. Some patients are over-enthusiastic in this regard and as a result frequently produce great injury to the hard and soft tissues of the mouth.

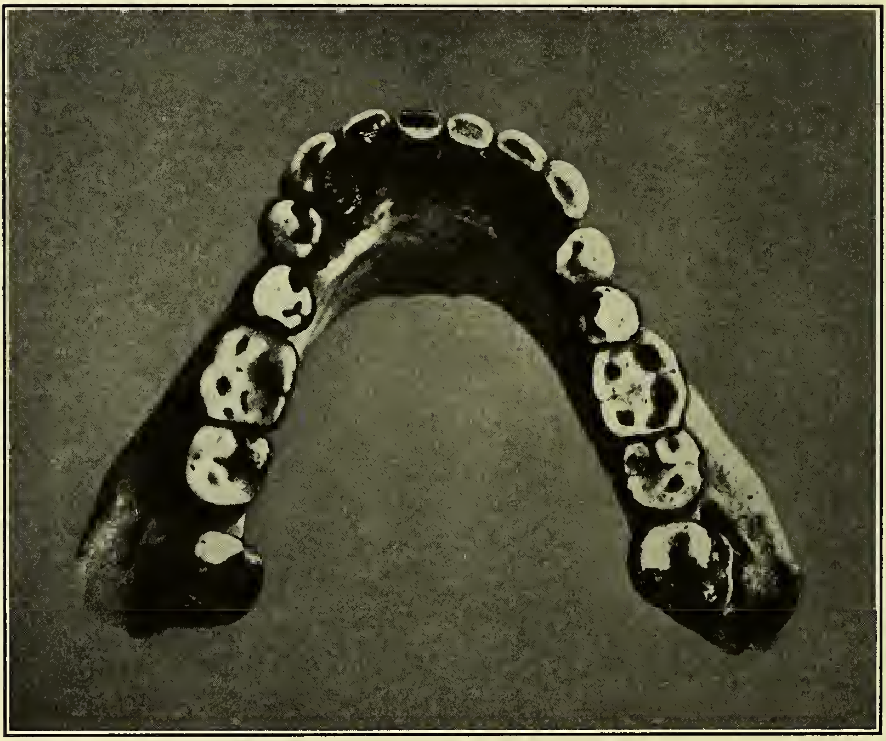


Fig. 791.—Abrasion of incisal and occlusal surfaces.

4. If due to gritting of the teeth (Bruxomania) administer bromides, apply an interdental splint, for use at night, and treat the cause.

Gritting of the teeth in adults may be due to nervousness incident to over-work, to over-activity of the brain and nervous centers from mental stress, or to neuroses emanating from reflex disturbances.

Gritting of the teeth at night in children is often due to vesical irritability, hyperacidity of the urine and rectal parasites. Render the urine alkaline by the administration of potassium salts and restriction to a vegetable diet; reduce irritability of the bladder with belladonna; remove rectal parasites with vermifuges and rectal injections. Systemic treatment of these cases should be referred to the physician.

Restorative Treatment of Abrasion.—In the milder cases, endeavor to limit the lateral excursions of the mandible, excessive movements of which frequently are present, by the insertion of judiciously placed gold fillings or inlays, building up a cusp here or there with this purpose in view. This should be carefully done to avoid occlusal trauma.

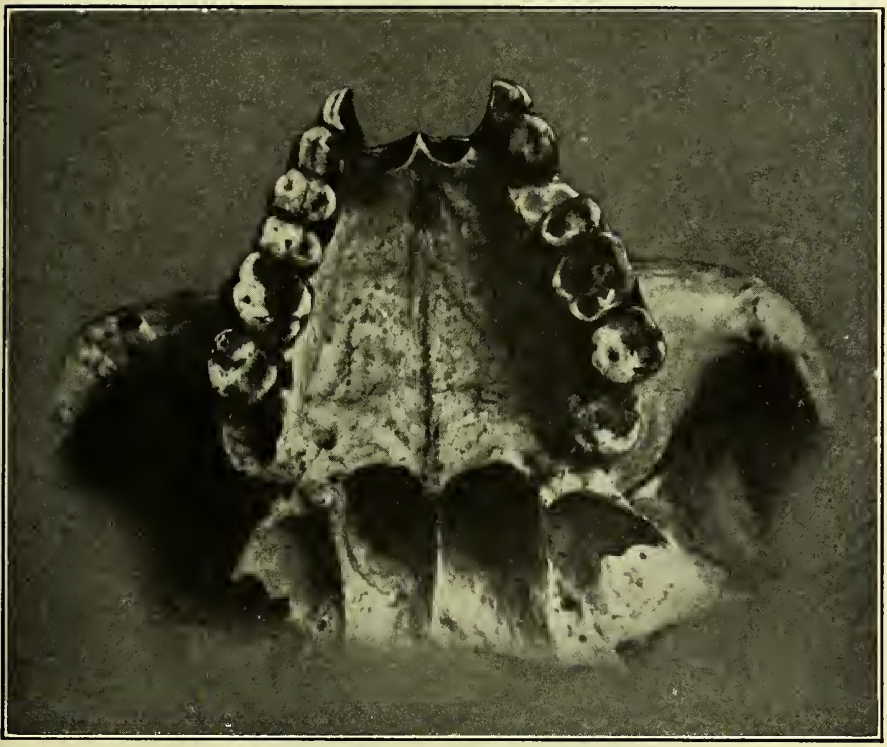


FIG. 792.—Abrasion of teeth of the upper jaw.

In cases of moderate wear of occlusal surfaces, the operation of "shoeing" may be resorted to, cutting cavities in the abraded surfaces and placing gold fillings or inlays, making no attempt to restore original tooth forms. Anchorage frequently may be obtained for these operations by insertion of gold or platino-iridium posts, without necessitating the devitalization of the pulp, although in some cases removal of the pulp is required. Root therapy operations in these cases are often difficult or impossible, due to the frequent presence of extensive secondary dentin deposits and obliteration of pulp chamber and canals.

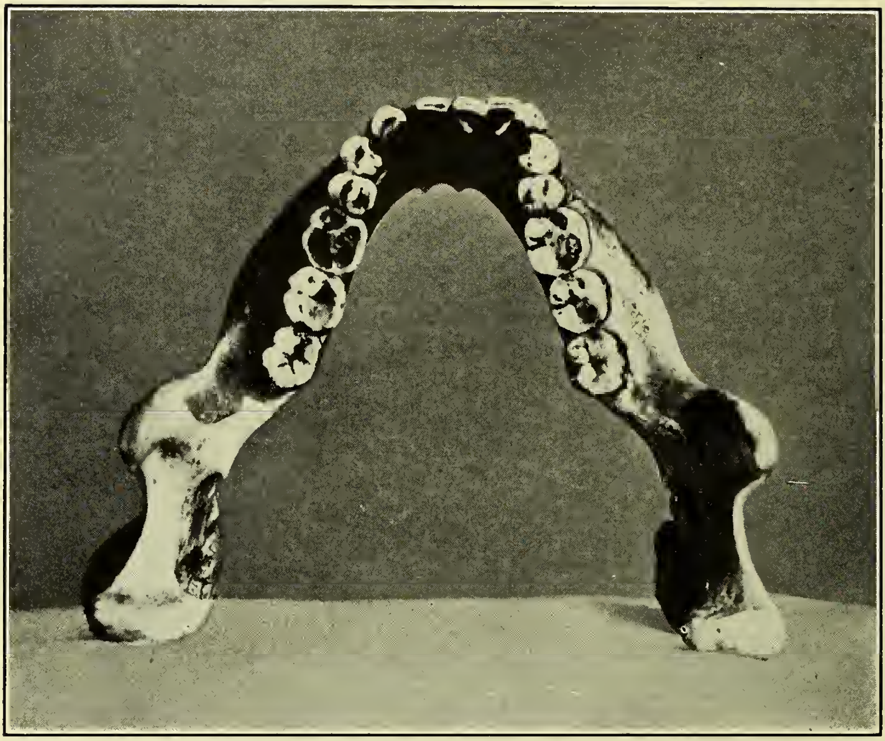


FIG. 793.—Abrasion of teeth of the lower jaw.

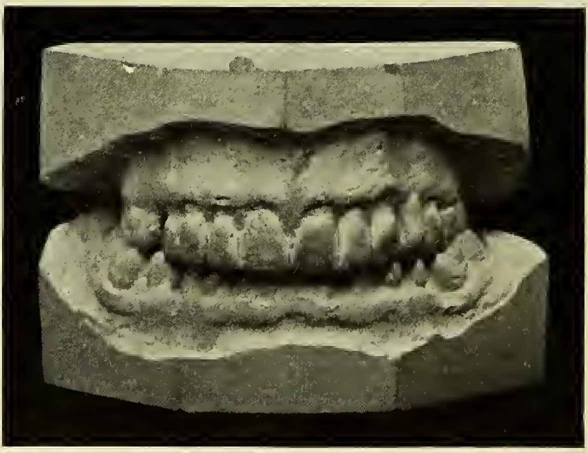


FIG. 794.—Tooth brush trauma (abrasion and gingival recession). (Courtesy of Dr. Isidor Hirschfeld and "Dental Items of Interest.")

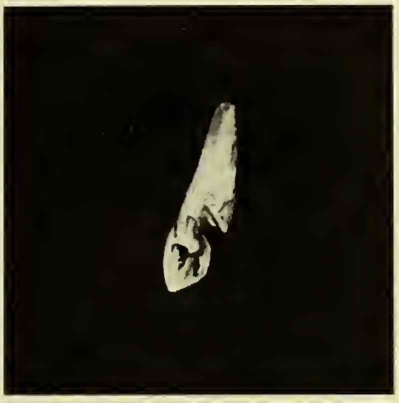


FIG. 795.—Lingual abrasion on an upper cuspid with excessive overbite.

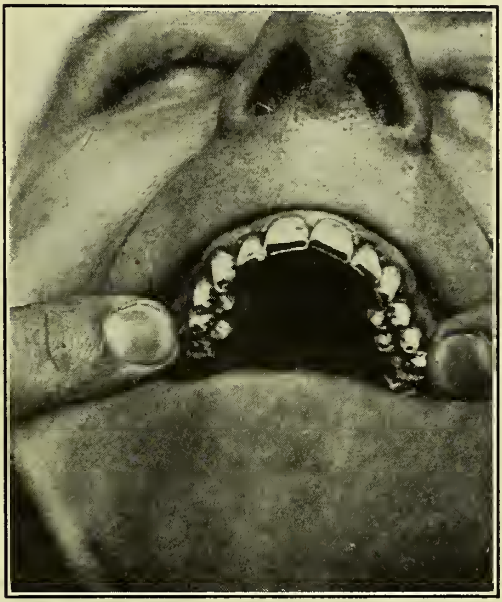


FIG. 796.—Hypoplasia of the enamel with incisal abrasion.

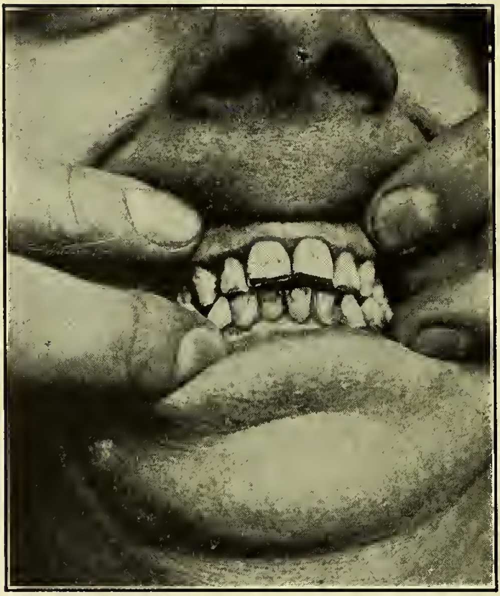


FIG. 797.—Same case as seen in Fig. 796, showing hypoplasia on lower anterior teeth and abrasion of uppers.

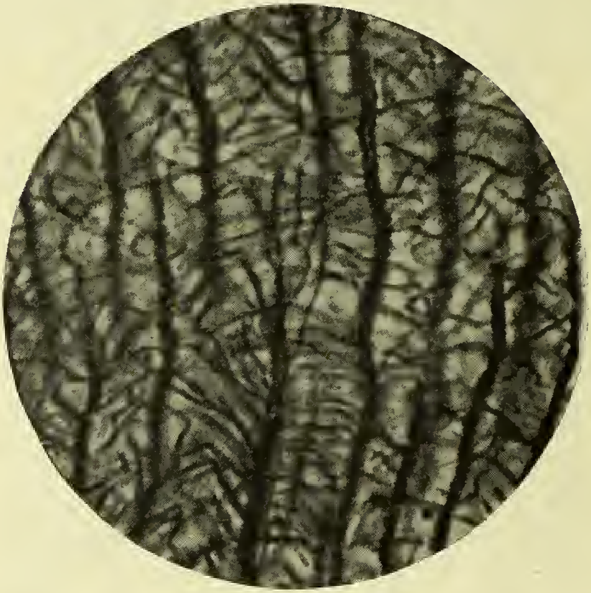


FIG. 798.—Dentinal tubules showing lateral anastomatic branches. (Courtesy of Dr. Harold K. Box.)

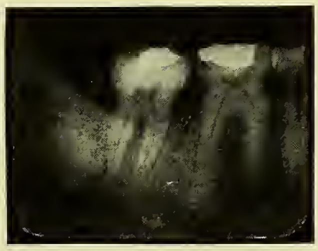


FIG. 799.—Bone condensation. Due to abrasion and trauma.

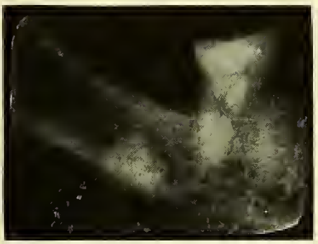


FIG. 800.—Condensed bone. Abrasion and trauma.

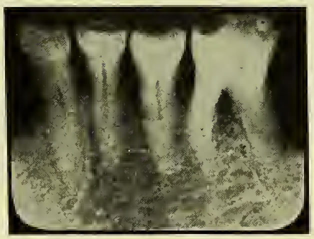


FIG. 801.—Abrasion and alveolar absorption.

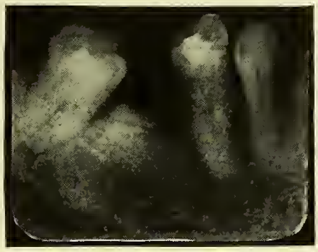


FIG. 802.—Condensing bone mesial to second molar due to drifting of second molar. Abrasion and trauma.

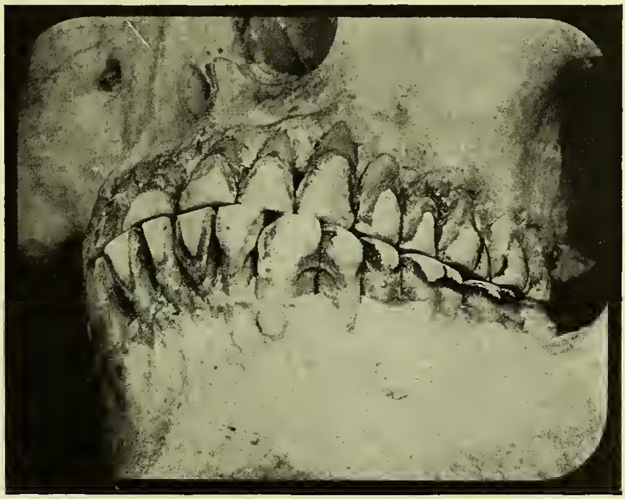


FIG. 803.—Hindu skull showing abrasion and absorption of the alveolar process. (Courtesy of Dr. Isidor Hirschfeld and "Journal of Dental Research.")

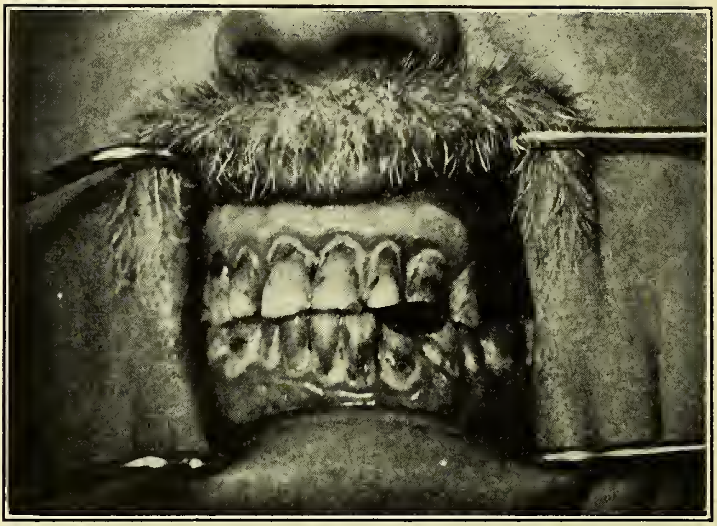


FIG. 804.—Non-occlusion due to pipe smoking. The tooth structure has been worn away to the form of the pipe stem. Profuse deposits and periodontal destruction. (Courtesy of Dr. Samuel C. Miller and Journal of Dental Research.)

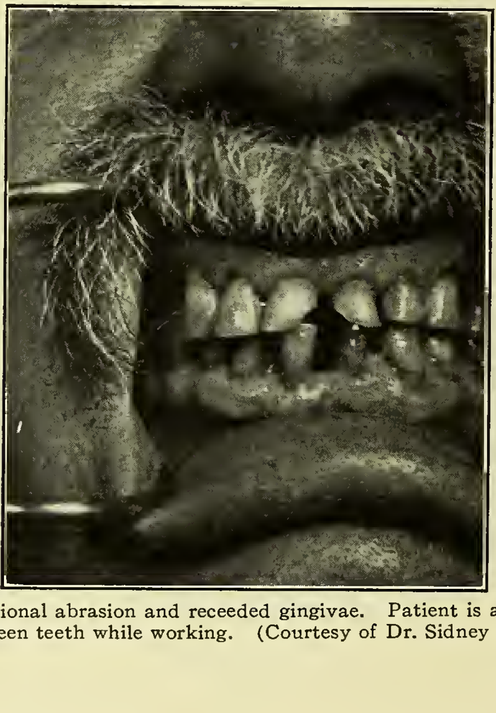


FIG. 805.—Occupational abrasion and receeded gingivae. Patient is a cobbler and holds nails between teeth while working. (Courtesy of Dr. Sidney Sorrin.)

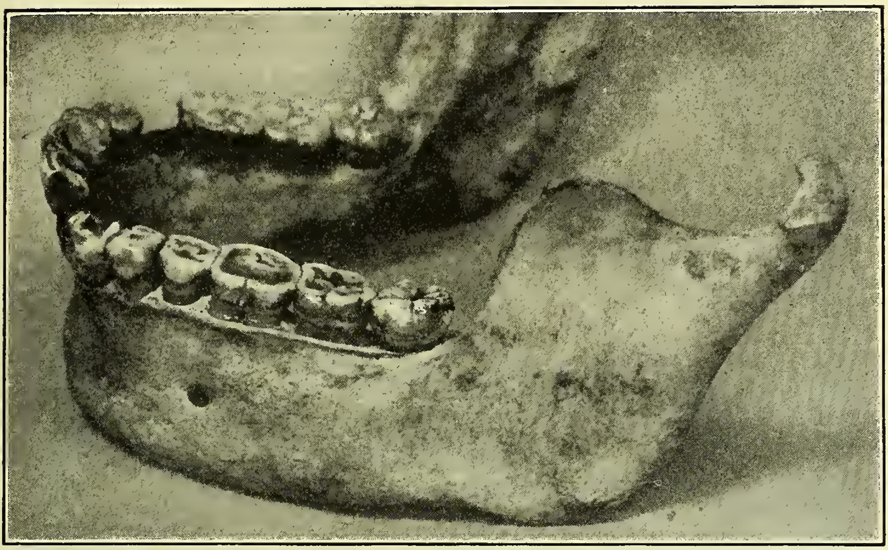


FIG. 806.—Australian aboriginal mandible showing abrasion and healthy alveolar process. (Courtesy of Dr. Isidor Hirschfeld and "Journal of Dental Research.")

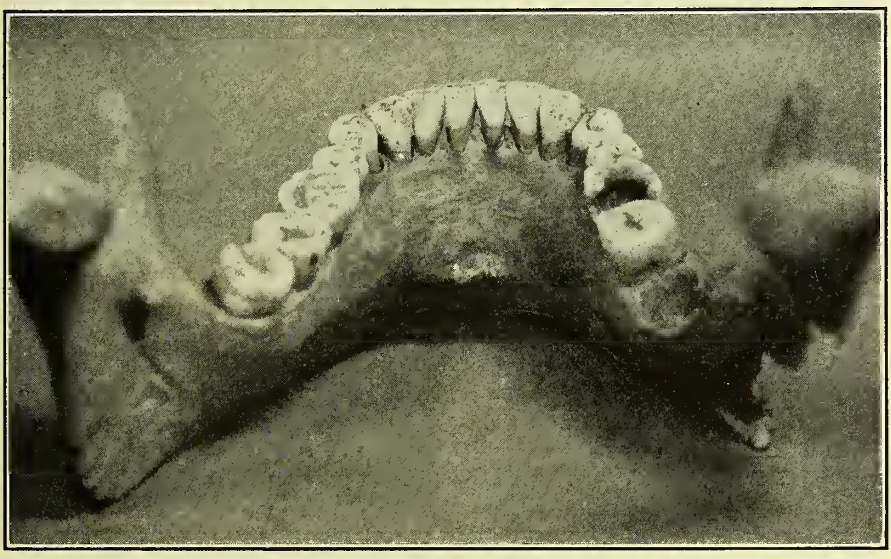


FIG. 807.—Aztec mandible showing abrasion. Absorption of alveolar process in incisor region. (Courtesy of Dr. Isidor Hirschfeld and "Journal of Dental Research.")

In extensive cases of great wear, the operation of "opening the bite" may be attempted, placing crowns or inlays on the posterior teeth, bridges or removable dentures in any existing spaces, and building up and restoring to original form the anterior teeth with fillings or porcelain crowns.

INTERPROXIMAL WEAR OF THE TEETH

Interproximal wear is a form of abrasion, consisting in abnormal wearing away of the contact points, as a result of a constant sliding against each other of proximating teeth, during the act of mastication. The contact points become worn and flattened, frequently presenting well-marked facets, in consequence of which condition a drifting together of adjoining teeth occurs, and a shortening of the total length of the arch results, thus diminishing the total masticating surface.

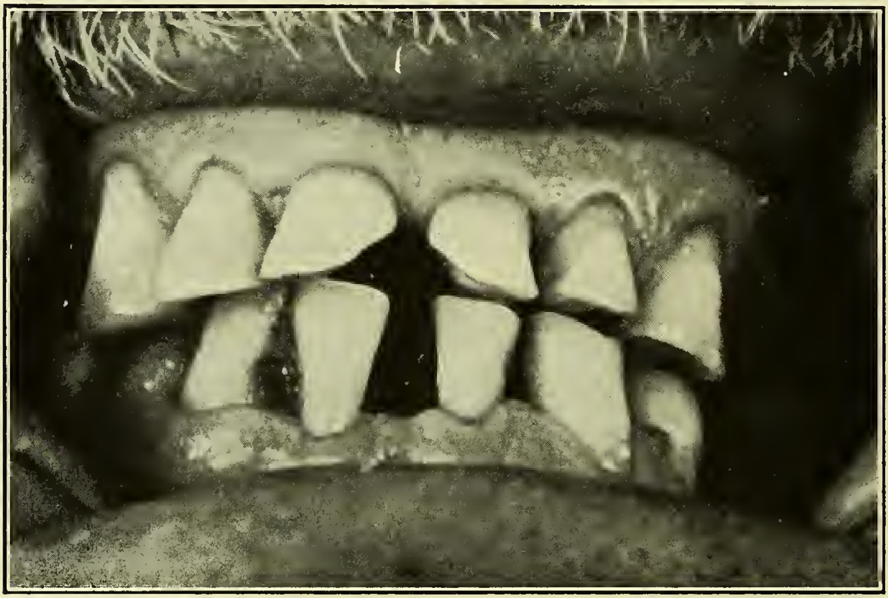


FIG. 808.—Mechanical abrasion. This patient is a cobbler and constantly holds nails between the teeth while working.

Symptoms of Interproximal Wear.—The contact points are worn and flattened. Packing of food into the affected interproximal spaces occurs, causing discomfort to the patient. As a result, fermentation and putrefaction of the food occurs, ultimately producing cavity formation, gingivitis, resorption and destruction of gingival, pericemental and bony tissues, with general periodontal disturbance. In the early stages, tumefaction, redness and tenderness of the gingivae are the most noticeable symptoms; later, absorption, accumulation of food debris, pus formation and concomitant conditions may and frequently do supervene.

Treatment of Interproximal Wear.—Establish normal contact points. Separate the teeth, prepare cavities and insert fillings or inlays, sometimes building the contact points overfull to allow for possible subsequent wear. Treat the affected soft tissues by the appropriate prophylactic and curative measures. Similar interproximal conditions are sometimes the result of irregularities of the teeth, abnormally shaped proximal surfaces, or loss of teeth, with consequent drifting. Appropriate treatment to remove the cause or remedy the condition is indicated, viz.; treatment of irregularities, widening existing spaces where teeth are lost, insertion of bridge work and restoration of perfect contacts.

SENILE DECAY

This is a form of decay occurring in old people, beginning at the cemento-enamel junction on labial, buccal or proximal surfaces, in cases of recession of the gingival tissues. It frequently occurs on teeth whose enamel has previously been immune to caries in these localities. As the gingival tissues recede, caries is likely to make its way in the cementum and extend up the side of the exposed root. It is often associated with uncleanliness in these areas, the result of poorly conducted oral hygienic measures incident to old age. Accompanying it is usually a long continued gingival inflammation with recession and the formation of a site particularly favorable to plaque formation. Most of the cavity being located in cementum, the difficulty of securing good cavity margins and the marked tendency to a recurrence of decay are apparent. The treatment consists in the correct application of oral hygienic measures and the insertion of fillings or inlays.

Bibliography

1. Prinz, Herman: "American Text-book Operative Dentistry," 6th ed., p. 596.
2. Kirk, Edward C.: Dental Items of Interest, vol. XXIV, July 1902, p. 511.
3. Kirk, Edward C.: Idem.
4. Miller, W. D.: Dental Cosmos, 1905, p. 18.
5. Marshall, Jno. A.: American Jour. Physiology, vol. XLIII, no. 2, May 1917, p. 212.
6. Preiswerk, Gustav: Zahnhielkund, 1903, p. 200.
7. Miller, W. D.: Dental Cosmos, Jan., Feb. and June, 1907.
8. Guilford, S. H.: Lectures.
9. Tomes, Sir. Charles S.: "Manual of Dental Anatomy."
10. Miller, W. D.: Dental Cosmos, Jan., Feb. and June 1907.
11. Stillman, Paul R. and McCall, J. O.: "Text-book of Periodontia," McMillan Co., New York, 1922.

Black, G. V.: "Operative Dentistry," 6th ed., vol. 1, p. 39.
Head, Joseph: Dental Cosmos, 1907, p. 801; 1910, p. 46.
Frissell, H. E. and Vogt, C. C.: Jour. Amer. Dent. Assoc., 1926, p. 748.
Rickert, U. G.: Jour. Amer. Dent. Assoc., 1924, p. 391.
Starr, Henry E.: Human mixed saliva, etc., Jour. Biolog. Chemistry, Sept. 1922, pp. 35–43.
Prinz, Herman: "Diseases of the Soft Structures of the Teeth," p. 86.
Buckley, J. P.: "Dental Materia Medica and Therapeutics," Blakiston, Philadelphia.
Burchard, H. H. and Inglis, O. E.: "Dental Pathology and Therapeutics," 6th ed., Lea and Febiger, Philadelphia, 1920.
Darby, Edw. T.: Dental Cosmos, vol. XXXIV, 1892, p. 629.
Bunting, R. W. and Wixon, Florence: Jour. Amer. Dent. Assoc., 1917, p. 81.
Maria and Pietkiewicz: Dental Cosmos, 1907, p. 525.
Bunting, R. W.: "Oral Pathology," p. 149.
Hartman, Leroy L.: A new and effective means for dental desensitization, N. Y. Dent. Jr., vol. 6, no. 2, p. 39.

CHAPTER XXV

SERVICE FOR SPECIAL TYPES OF PATIENTS—CARE OF CHILDREN—ADOLESCENTS—INVALIDS AND CONVALESCENTS—NEURASTHENICS AND NEUROTICS—PREGNANT WOMEN—THE BED-RIDDEN

In many instances the routine operative procedures as adapted for the usual or ordinary type of patient must be modified to meet the needs of special cases. Young or adolescent patients, invalids, convalescents, neurotics or neurasthenics, pregnant women and patients who are ill and confined to bed must receive special consideration and care. Methods of handling these various classes of patients from the standpoint of the operative dentist are discussed in this chapter.

THE CARE OF CHILDREN'S TEETH—CHILDREN'S DENTISTRY

Coincident with the rapidly increasing knowledge of preventive dentistry, there has arisen a realization of the importance of systematic and close supervision of the dental needs of the young. The rapid spread of the oral hygiene movement, with the establishment of dental clinics in the public schools and other institutions for ministering to the needs of children has been discussed in the chapters on "Preventive Dentistry," to which the reader is referred. It is now realized that children's dentistry is an important part of dental service and that much more stress must be laid on it in the future than has been the practice in the past. As a result, many of the dental colleges are establishing separate clinics for children's dentistry, where these little patients can be given special consideration and attention and where continued research may be conducted into many at present unknown phases of this rapidly developing specialty.

Pedodontia, or children's dentistry opens an inviting field for men and women specially interested and equipped for this important work. The word *pedodontia* is derived from the Greek *pais*, child and *odous*, tooth, meaning that branch of dentistry which has for its purpose the study and treatment of children's teeth and mouth conditions. A pedodontist is a specialist in this field. A closer cooperation is gradually being established between the pedodontist and the pediatrist (specialist in children's diseases), to the advantage of both and to the improvement of the physical welfare of the child. The dental and medical professions, humanitarians, and in fact many of the leading minds of the entire nation are now centering on children's dentistry, realizing that only through concentration on pre-natal and early post-natal influences can a high type of dental mechanism and, through that, the health standards of future generations be raised and maintained. The "Child's Bill of Rights" of former President Hoover has now become a classic and will bear repetition here.

THE CHILD'S BILL OF RIGHTS

"The ideal to which we should strive is that there shall be no child in America:

That has not been born under proper conditions;
That does not live in hygienic surroundings;
That ever suffers from undernourishment;
That does not have prompt and efficient medical attention and inspection;
That does not receive primary instruction in the elements of hygiene and good health;
That has not the complete birthright of a sound mind in a sound body;
That has not the encouragement to express in fullest measure the spirit within which is the final endowment of every human being."

Problems Involved.—The management of children in the dental office is quite largely a psychological problem. Many dentists, although possessing great skill in dealing with cases daily arising in routine dental practice, do not possess the qualifications necessary to successfully cope with the many difficulties involved in handling children. Owing to frequent natural timidity and restlessness on the part of these little patients, the small size of the oral cavity, and the increased amount of salivary secretion usually present, the problems involved are manifold. It is with patients of this type that women dentists are often better adapted by nature than men to cope successfully with the situation. However, it is true that a firm manner, usually supposed to be predominant in the male sex, occasionally will be necessary in handling certain types of children, although the opposite attitude of kindliness and sympathy frequently will produce the desired effect with many of them.

The necessary qualifications on the part of the dentist for successfully administering to the dental needs of children are tact, knowledge of human nature, especially child psychology, patience, extreme kindness, sympathy, firmness and will power when necessary, operative skill, and judgment in the selection of the materials and remedies used. Every child should be studied closely, and the method of handling adapted to its individual needs and characteristics. Each case must be handled differently, and a decision must be reached quickly as to what attitude to adopt. Often, children have had a dread of the dentist instilled into them at home. Parents should be strongly cautioned against this.

Many dentists do not fully appreciate the importance of the proper care of children's teeth, and many others, unfortunately, knowingly minimize its importance, because of their dread of handling cases of this nature, with the result that, frequently, untold injury is done these little patients, through neglect or carelessness. If the child is carefully studied and properly handled, he often will submit willingly to operations to which the adult patient will subject himself with poor grace. It should be remembered that these little men and women are soon to become the representative citizens of the community, and that they deserve all the care and skill of which the dentist is capable.

THE FIRST VISIT

At the first visit to the operating room the little patient often is filled with curiosity, timidity, or is markedly anticipative of dreadful consequences. It is highly important that this first experience should be made as pleasant and free from pain as possible, else disastrous consequences may result, and it may be impossible to induce him to submit to further ministrations. The following procedures usually may be adopted by the dentist at this first visit with beneficial results:

First.—No difficult or painful operation should be attempted, unless absolutely necessary.

Second.—If relief from pain is demanded, apply a simple, palliative treatment to the tooth. This occasionally may be done with the child seated in the lap of the mother or nurse, if very young.

Third.—Endeavor at once to become acquainted with and gain the confidence of the patient.

Fourth.—Avoid deceiving the child or concealing instruments.

Fifth.—If application of medicaments is necessary, use those which are most agreeable in taste and color.

Sixth.—Entertain the child with pleasant conversation, and attempt to interest it in pictures, the chair, or surrounding objects.

INSTRUCTIONS TO PARENTS

Definite and careful instructions should be given parents in regard to the care of the teeth of their offspring. Every effort should be made to impress them with the importance of constant surveillance in regard to daily cleansing, regular and frequent visits to the dentist, care of

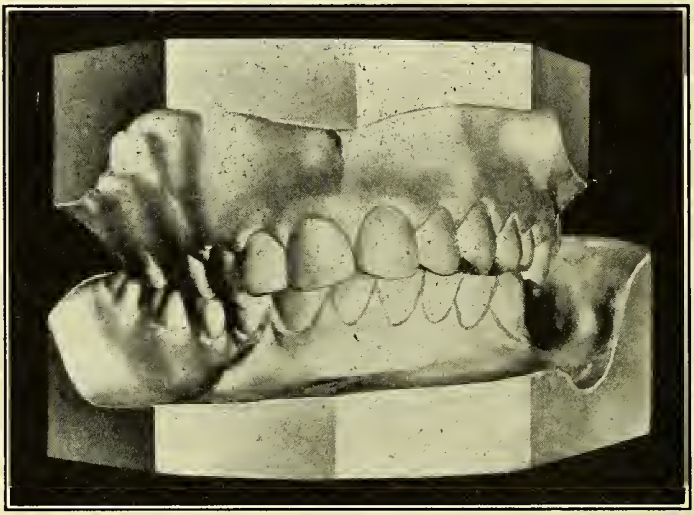


FIG. 809.—Malocclusion due to early loss of lower teeth of left side.

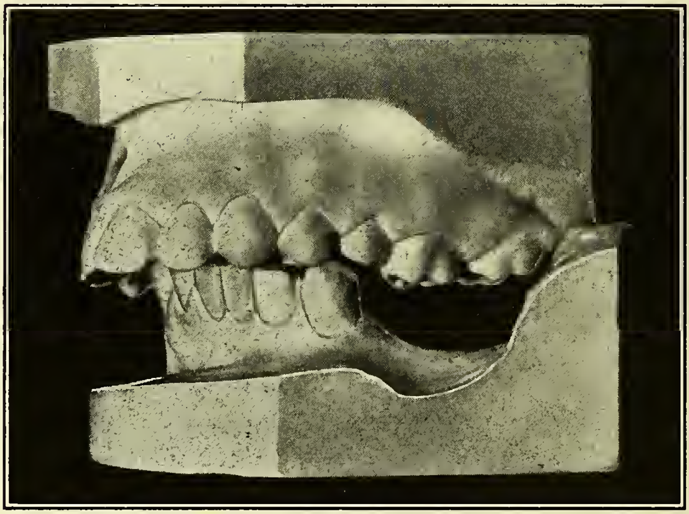


FIG. 810.—Malocclusion due to early loss of lower teeth of left side. Lateral view of case shown in Fig. 809. Note lateral shifting, protrusion of upper anteriors and elevation of posterior upper molars from non-occlusion.

the temporary and permanent dentures, and especially of the necessity for preservation of the first permanent molar. Health relationships should be fully explained. Figs. 809 and 810.

The importance of correct diet containing the proper mineral, vitamin and activating principles, proper mastication, exercise, sunlight, radiant energy, fresh air in school and nursery, should be stressed. A thorough examination of the nasal passages and fauces should be made for the possible presence of nasal obstructions, deflected septum, adenoids and diseased tonsils. If found, they should be brought to the attention of the parent with recommendations for their correction. Beginning irregularities of the teeth should be early referred to the orthodontist.

EARLY PREVENTIVE MEASURES

Regular and systematic cleansing of the mouth should be begun soon after birth, before the eruption of the teeth. The mouth should be carefully and gently swabbed by the mother or nurse with a solution of boric acid, milk of magnesia, or formalid-magnesia, by means of a soft sterile cloth, napkin, or absorbent cotton, wrapped around the finger or an orange-wood stick. The danger of possible wounding of the delicate soft tissues through the too vigorous use of these measures should be explained. Redoubled care should be instituted as soon as the teeth begin to appear, using the same method, or a small, fine bristle brush. A mucilage brush, or the smallest size child's brush, from which some of the bristles have been cut from the heel, may be utilized in the beginning. Floss silk also should be passed carefully between the teeth. As soon as the child is old enough, it should be taught to cleanse its own mouth, and

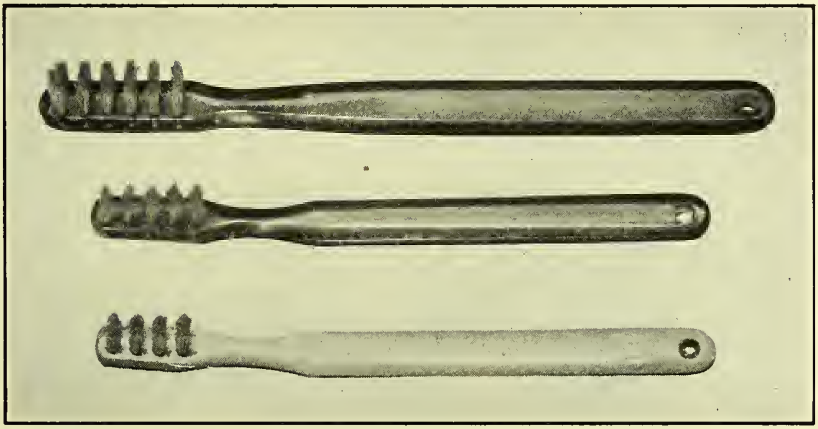


FIG. 811.—Brushes for children.

told why it is necessary to do so. Dentrifrices should be of a pleasant taste. Incitement of fear of the dentist should be avoided. If candies and other sweets are desired, they may be used without harm, provided they are not eaten to excess, and the mouth is cleansed after eating. Fig. 811.

DENTITION

The period of dentition is often a trying one for both mother and offspring. Some children pass through this period with very little trouble, while others become subject to morbid local inflammatory and septic disturbances of the gum over the erupting tooth, as well as grave systemic manifestations of a reflex nature, including loss of appetite, fretfulness, sleeplessness, nervous irritability, convulsions, chorea, skin

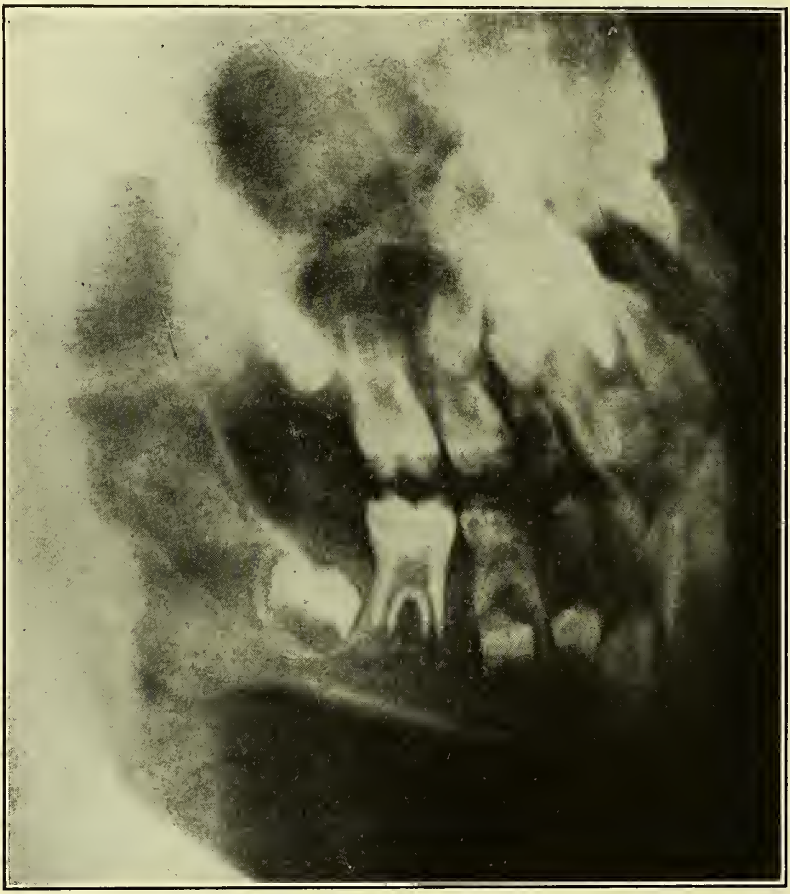


FIG. 812.—Process of eruption. About eight years.

eruptions, digestive disturbances, diarrhea and many others. A description of these disturbances usually is confined to works on pathology and pediatrics, and will not be entered into here. Fig. 812. However, it may be said that they are largely the result of pressure on the terminal nerve endings of the overlying gum or of the underlying dentinal papilla and pulp at the end of the forming root. Quick relief frequently is afforded by the operation of lancing the gum and the local application of antiseptic washes. The graver constitutional manifestations usually fall into the hands of the physician. Great harm may be done if the lancing operation be performed too early, through the formation of a band of cicatrical tissue over the advancing crown, which may greatly impede its further progress, instead of facilitating its eruption. As a general rule, lancing of the gum for this purpose should not be practiced unless the tooth is very near the surface, and the overlying tissues are stretched and ischaemic.

PERIODS OF ERUPTION

The following table of Stellwagen[1] gives the average periods of eruption of the deciduous or temporary teeth.

PERIODS OF ERUPTION OF THE TEMPORARY TEETH

Group 1.—Lower central incisors. Time of eruption, 7 months. Duration of eruption, 1 to 10 days. Interval, 2 to 3 months.

Group 2.—Upper central and lateral incisors. Time of eruption, 9 months. Duration of eruption, 4 to 6 weeks. Interval, 2 months.

Group 3.—Lower lateral incisors. Time of eruption, 12 months.

Group 4.—First molars. Time of eruption, 14 months. Duration of eruption, 1 to 2 months. Interval, 4 to 5 months.

Group 5.—Cuspids. Time of eruption, 18 months. Duration of eruption, 2 to 3 months. Interval, 3 to 5 months.

Group 6.—Second molars. Time of eruption, 26 months. Duration of eruption, 3 to 5 months.

In the United States the eruption of the lower lateral incisors usually precedes that of the upper, and the average periods of all of the teeth are frequently slightly earlier. Special care should be observed during this period in regard to cleanliness, proper clothing and diet. Children at this age seem to be particularly subject to intestinal disturbances. They may be due to reflex stimulations of the tenth nerve or to faulty diet.

The following table gives the average period of eruption of the permanent teeth:

PERIODS OF ERUPTION OF THE PERMANENT TEETH

First molars	6 to 7 years
Central incisors	6 to 8 years
Lateral incisors	7 to 9 years
First bicuspids	10 to 12 years
Second bicuspids	10 to 12 years
Cuspids	10 to 12 years
Second molars	12 to 14 years
Third molars and indefinitely beyond	17 to 30 years

ABSORPTION AND DEVELOPMENT OF ROOTS OF DECIDUOUS AND PERMANENT TEETH

It usually requires about three and one-half to four years for resorption of the roots of the temporary teeth, and the same period for formation of the roots of the permanent ones. The time required varies with the different teeth, but if the average time, as stated, is remembered, it will be of value in its bearing on the performance of root-canal operations in the mouths of children. Calcification of the roots of the first permanent molars usually requires much longer. The formation of the tip of the crown of this tooth usually begins at birth. However, the X-ray frequently should be resorted to in arriving at a decision as to

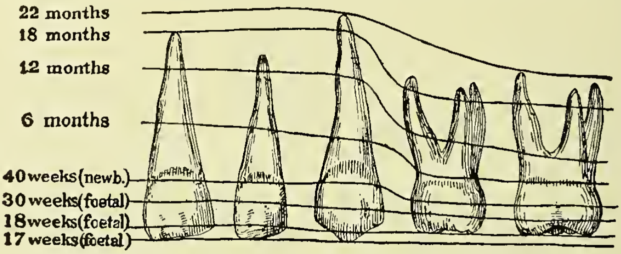


FIG. 813.—Calcification of the deciduous teeth. (Peirce.)

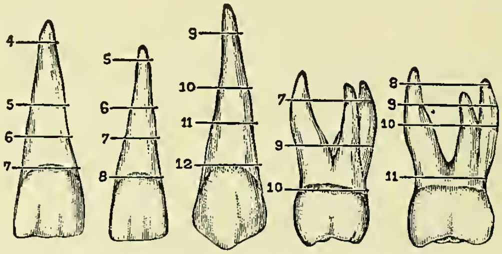


FIG. 814.—Decalcification of the deciduous teeth. The numbers indicate years. (Peirce.)

states of development. Usually the eruption of the permanent teeth is attended with very little disturbance, although the second, and more often the third molars are occasionally quite troublesome, their eruption being sometimes accompanied with marked local inflammation and reflex manifestations.

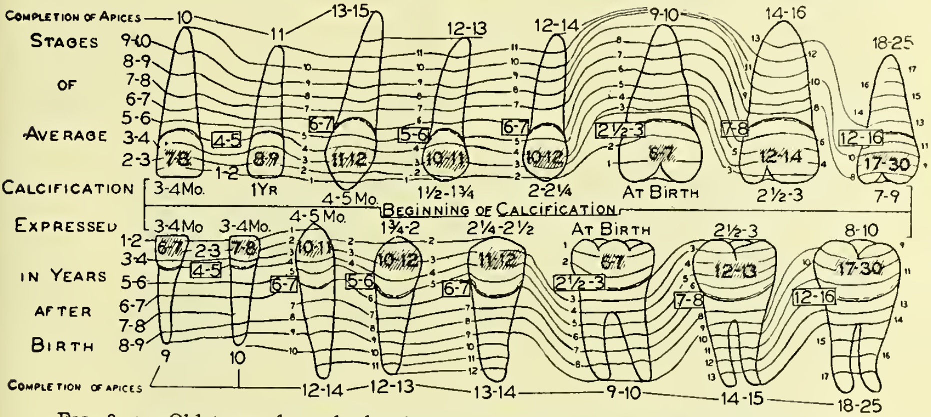


FIG. 815.—Old type of graph showing anatomically formed teeth located on occlusal plane. The shaded figures indicate their time of eruption. The growth lines are difficult to follow (Bödecker).

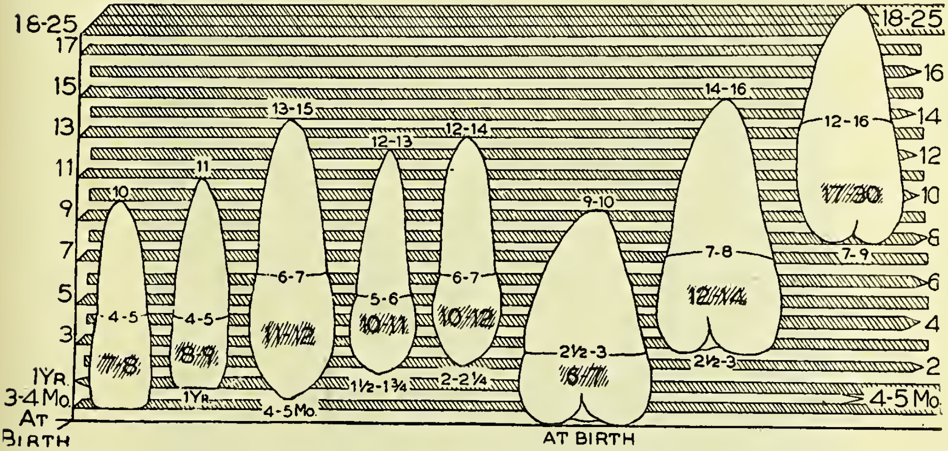


FIG. 816.—Graph showing periods of eruption and calcification of upper permanent teeth. Shaded areas indicate periods of eruption (Bödecker).

The periods of calcification and absorption of the deciduous teeth are represented in the tables of Peirce shown in Figures 813 and 814. Reference to the chart for calcification periods (Fig. 813), shows that calcification of the temporary central incisor begins at the 17th week of intra-uterine life. Average periods of eruption have previously been

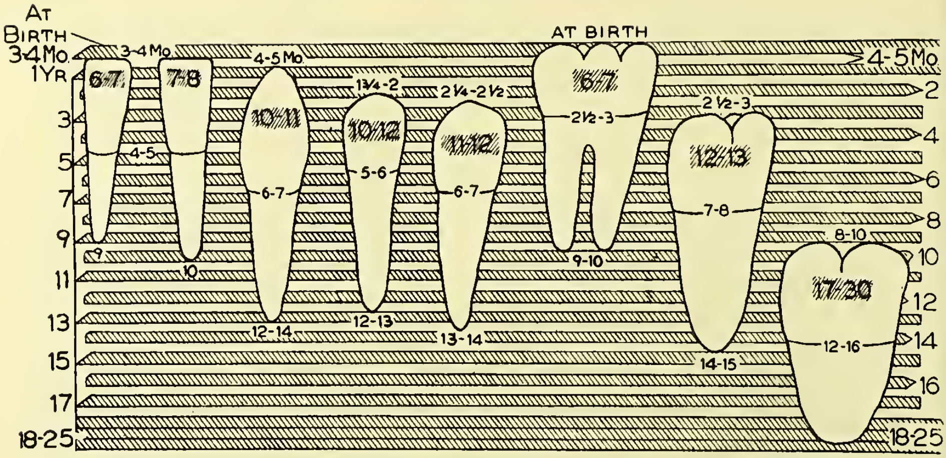


FIG. 817.—Graph showing periods of calcification and eruption of lower permanent teeth. Shaded areas indicate periods of eruption (Bödecker).

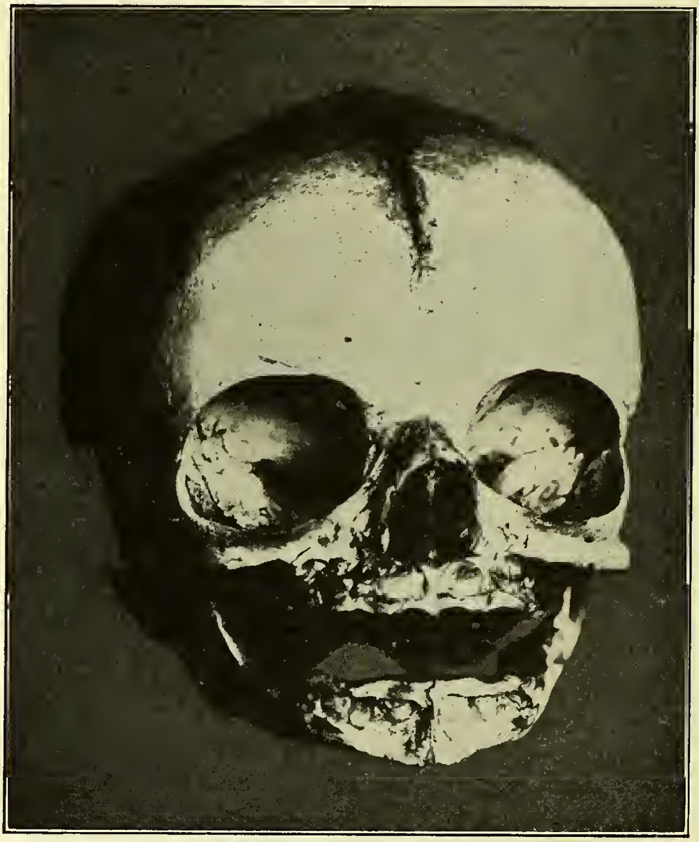


FIG. 818.—Skull of infant at birth.

given. Examination of Fig. 814 indicates in figures (4, 5, 6, 7, etc.) the average years at which progressive absorption of the roots of these teeth occurs. It must be remembered that the figures given in all of the tables showing calcification, absorption and eruption periods are merely averages and that there are frequently wide variations in different individuals. In rare instances, teeth have been found erupted at birth and temporary teeth are occasionally retained until middle age. The X-ray is valuable in determining the state of absorption and development of the roots of teeth and should often be resorted to for this purpose.

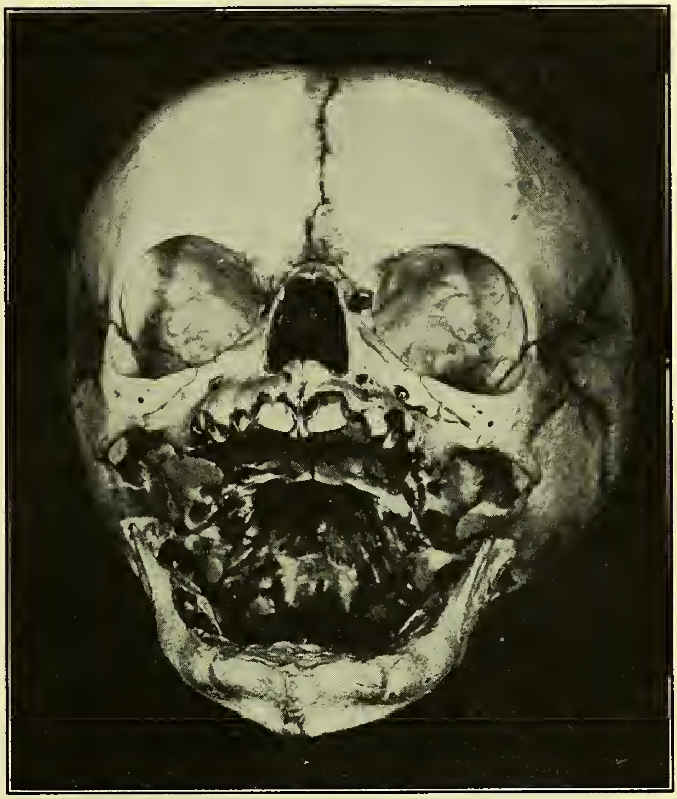


Fig. 819.—Infant skull. Four months after birth.

The absorption of the roots of the temporary teeth usually occurs concurrently with the advancement of the surface of the crowns of their successors, the pressure of the crown of the permanent tooth being definitely concerned in absorption of the temporary root lying against it. Death of the pulp of deciduous teeth has very little if any effect on the rate of absorption of these roots. Abscess with pus formation, however,

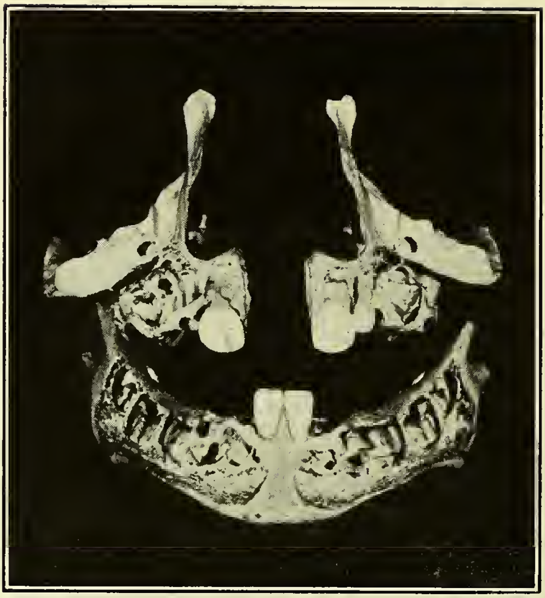


FIG. 820.—Eruption and development of the teeth and jaws, sixth to seventh month after birth.

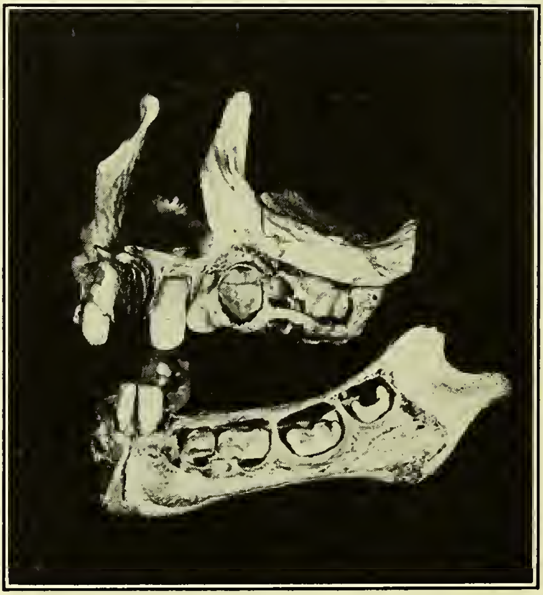


FIG. 821.—Lateral view of case shown in Fig. 820. Sixth to seventh month after birth

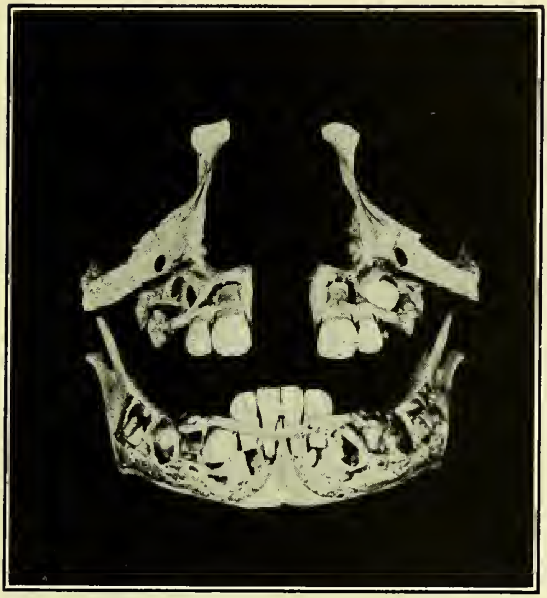


FIG. 822.—Dentition, eleventh to twelfth month.

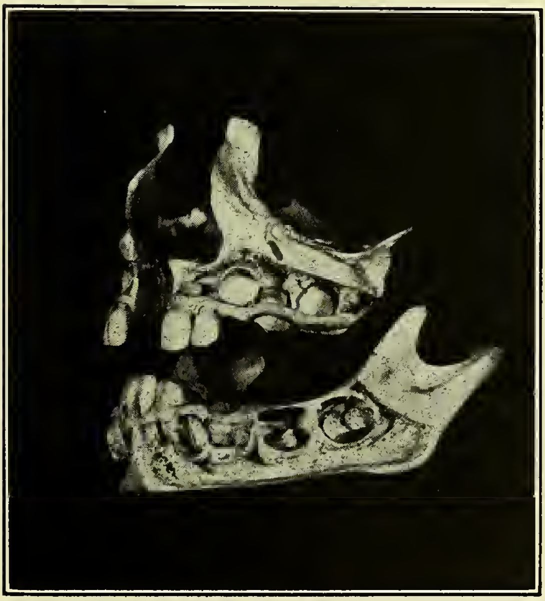


FIG. 823.—Lateral view of Fig. 822. Eleventh to twelfth month.

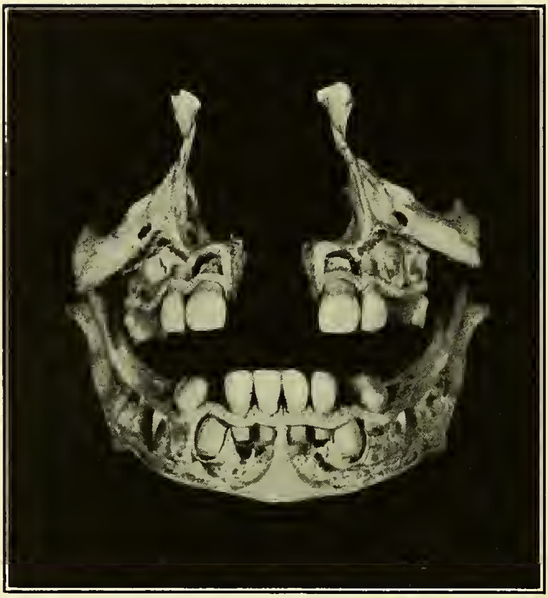


FIG. 824.—Dentition. Thirteen to fourteen months.

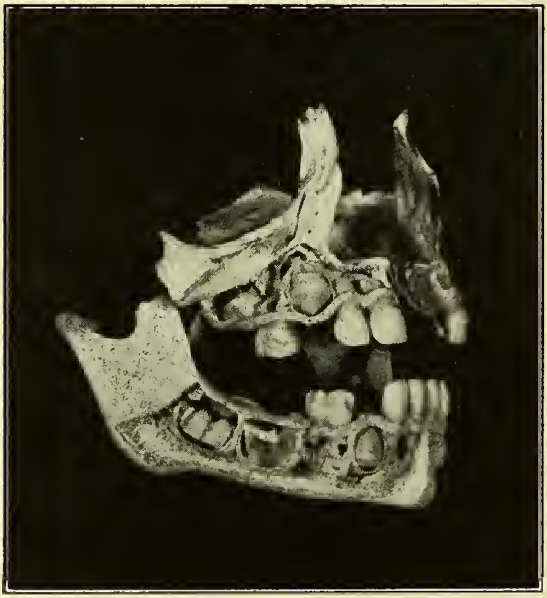


FIG. 825.—Lateral view of Fig. 824. Thirteen to fourteen months.

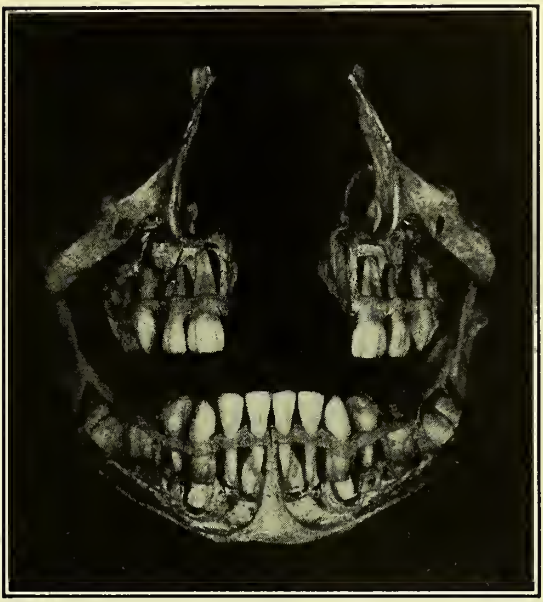


FIG. 826.—Dentition. Sixteen to eighteen months.

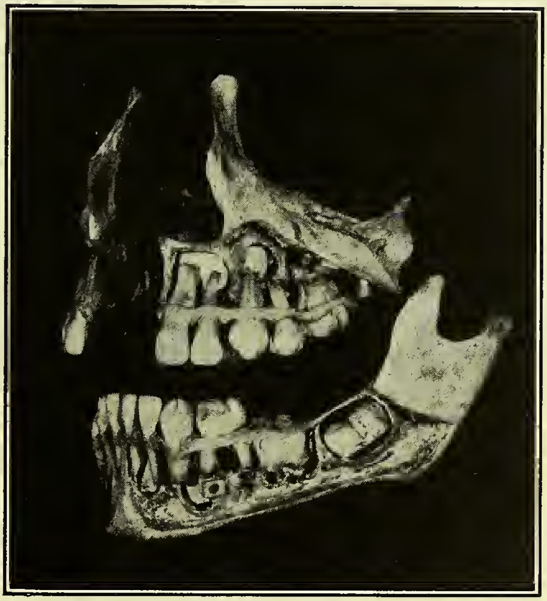


FIG. 827.—Lateral view of Fig. 826. Sixteen to eighteen months.

interferes with the absorptive process, and teeth in this condition may occasionally be retained for long periods beyond the normal time for their loss, thus producing irregularities in position or interference with the eruption of the permanent successors. Abscess of the root of a temporary tooth occurring at the time of enamel formation of the crown of the succedaneous permanent tooth may also, through injury to the enamel, often produce hypoplasia and malformation of the latter.

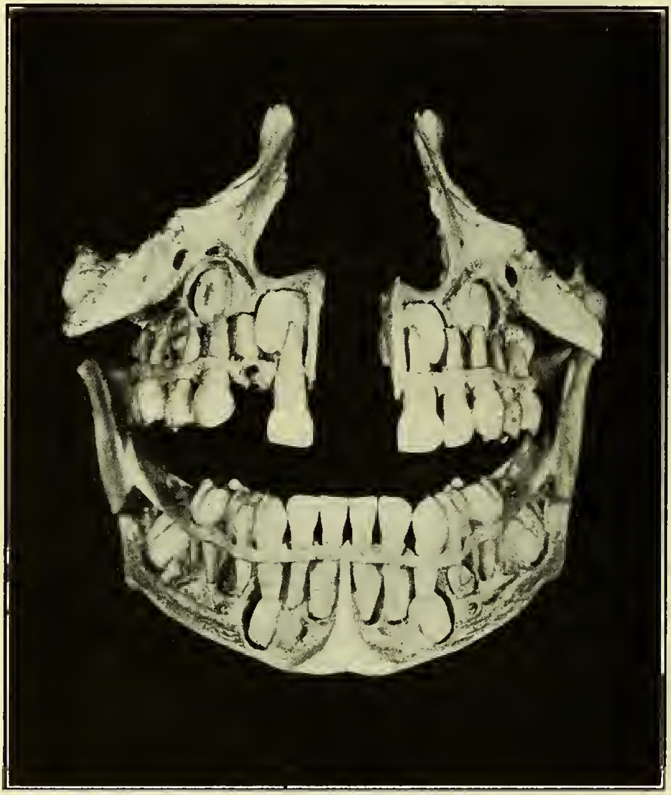


FIG. 828.—Dentition. Twenty-four to twenty-six months.

Average periods of calcification of the permanent set are shown in Figs. 815, 816 and 817. Reference to the illustrations seen in Figs. 818 to 835 inclusive will also afford much valuable information. Roentgenograms of individual cases will often reveal wide variations from these averages. A knowledge of the exact state of resorption and development of roots has a definite and important bearing on root canal therapy and filling operations.

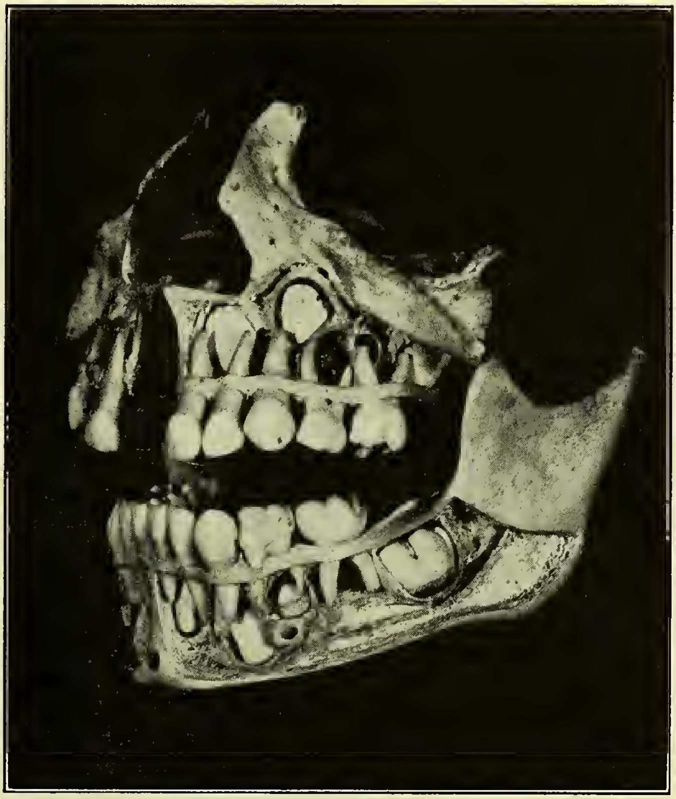


Fig. 829.—Dentition. Lateral view of Fig. 828. Twenty-four to twenty-six months.

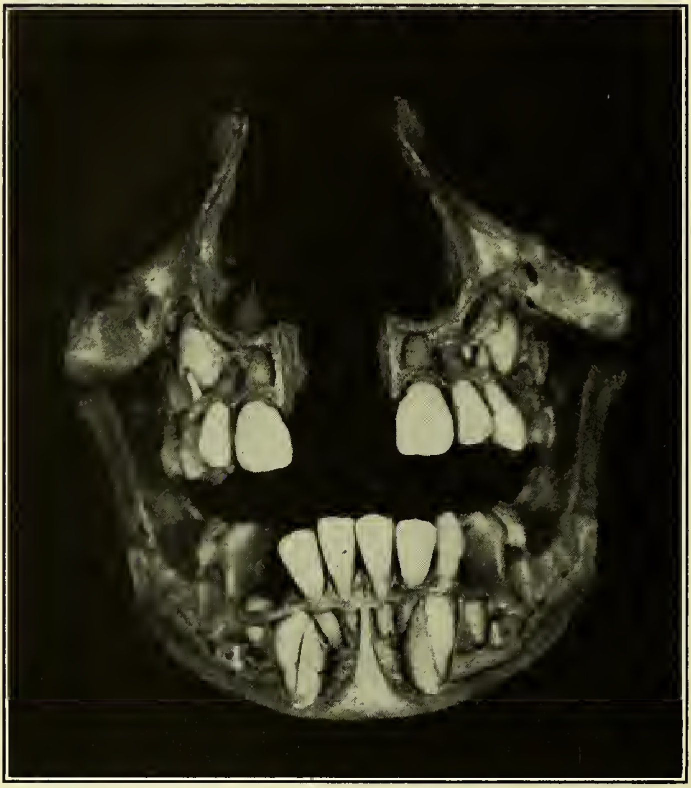


FIG. 830.—Dentition. Eight to nine years.

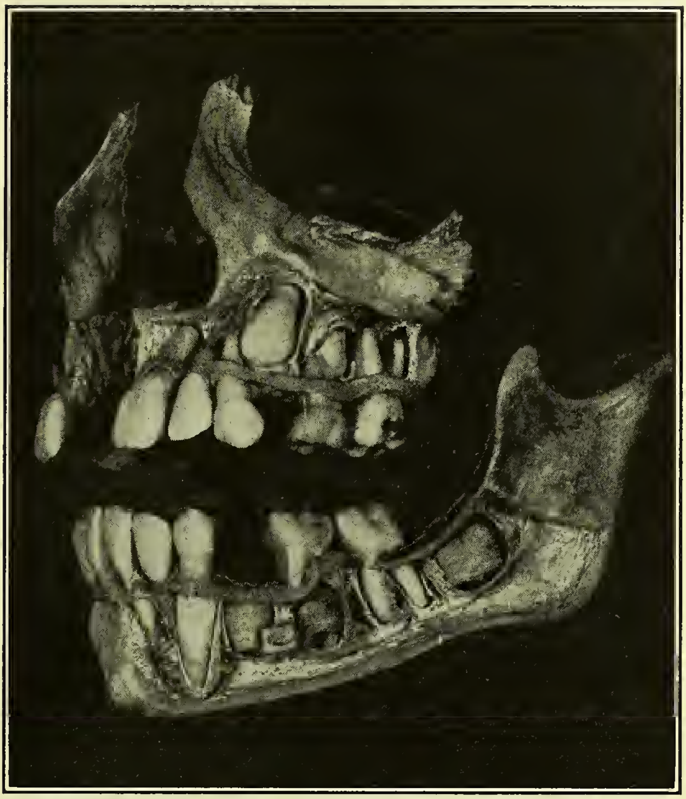


FIG. 831.—Lateral view of Fig. 830. Eight to nine years.

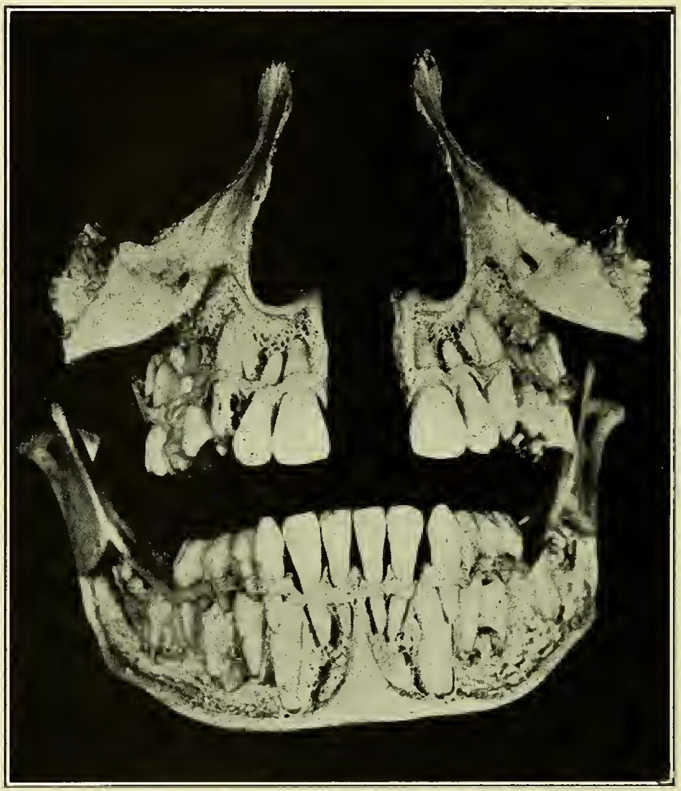


FIG. 832.—Dentition. Twelve to thirteen years.

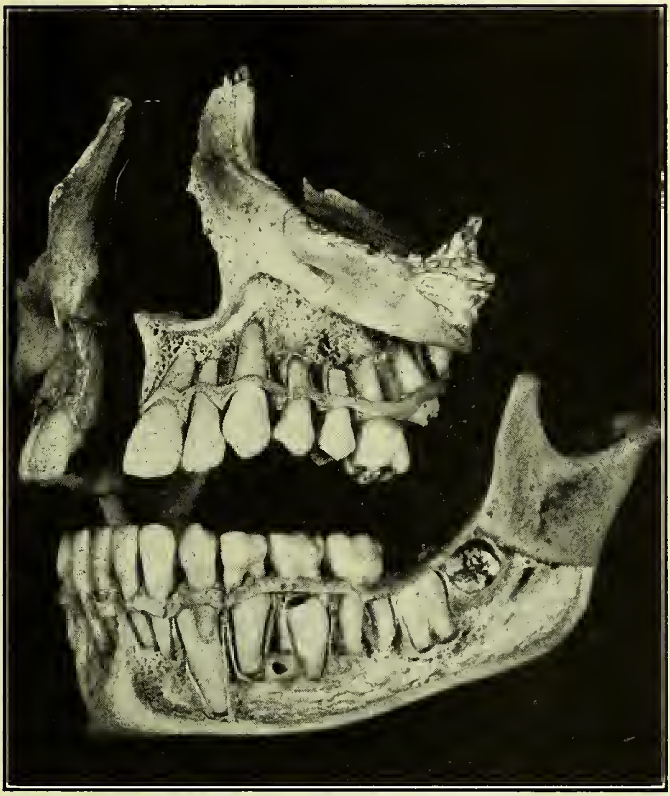


FIG. 833.—Lateral view of Fig. 832. Twelve to thirteen years.

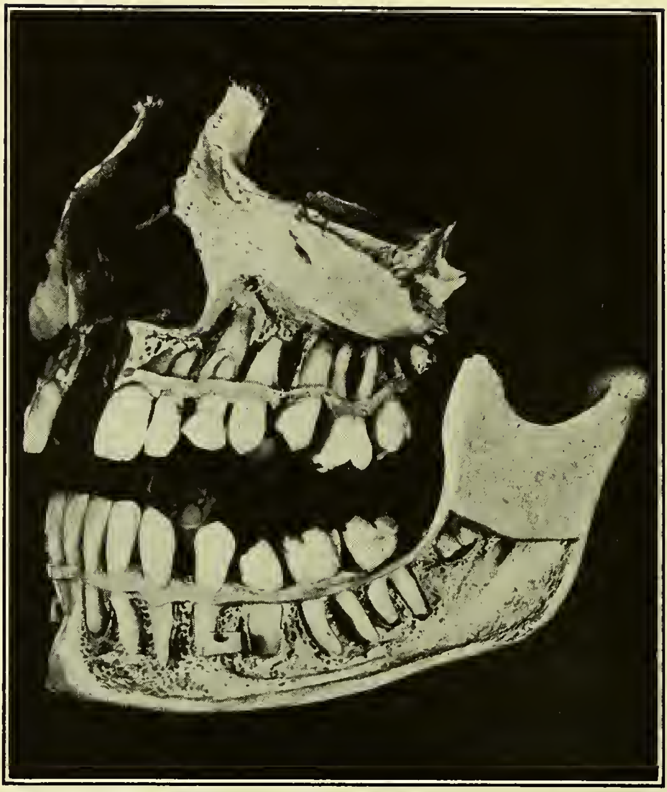


FIG. 834.—Dentition. Fourteen to fifteen years.

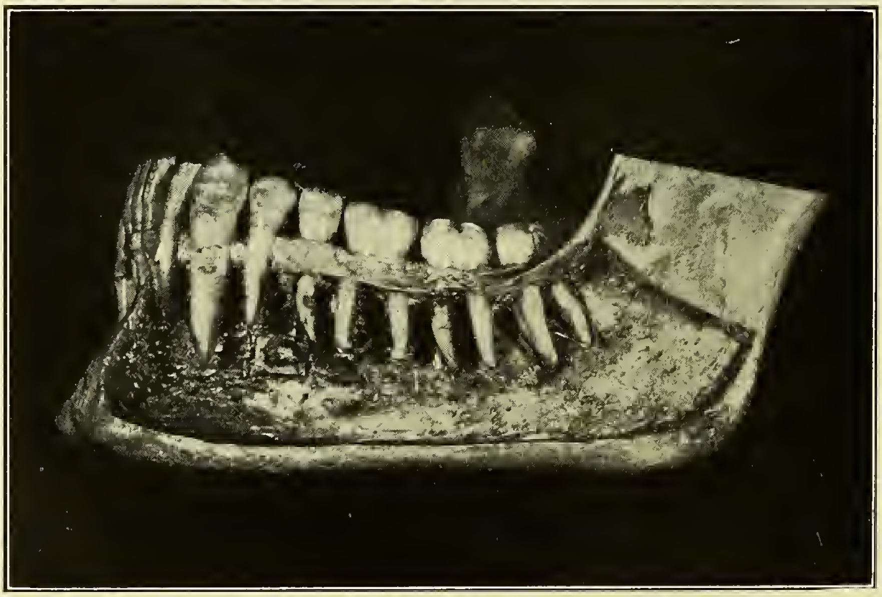


FIG. 835.—Dentition and calcification complete. Adult.

LANCING THE GUMS

During the eruptive periods of the deciduous teeth the operation of lancing the gums is frequently indicated to relieve pain, inflammation and other local and systemic disturbances arising as a result of the pressure of the overlying gum. This operation is rarely required with the permanent set. When indicated for deciduous teeth, it can more intelligently be performed by the dentist, owing to his knowledge of the anatomy of the parts, although in the majority of cases it is referred to the physician or pediatrist.

Position of the Child and Operator for Lancing the Gums.—If for the upper teeth, lay the child when quite young on a pillow across the nurse's lap. Place its head on or between the operator's knees, insert one or more fingers of the left hand into the mouth and obtain a proper guard by placing the thumb on one side and the forefinger on the other side of the alveolar process. For the lower teeth, seat the very young child in the lap of the operator, with its head against his breast. Pass the left hand around the infant's head, insert the left thumb into the mouth, with the fingers under the chin, thus steadying the jaw. If the child is old enough it may sometimes be seated in a special child's operating chair, if available.

With a sharp bistoury, around the blade of which (except at its point) floss silk or tape is wrapped, to prevent accident incident to struggling of the patient, make one or more incisions till the crown of the tooth is freed of the overlying gum tissue. Fig. 836. For the upper incisors, make a lineal incision slightly to the labial side of the cutting edge; for the lower incisors a similar incision slightly to the lingual side. The same procedure is followed with the cuspids, unless the point is protruding, in which case a crucial incision is indicated. For the molars, a crucial or X-shaped incision accomplishes the desired result. In case of partial eruption, small bands of gum tissue may best be removed with sharp-pointed curved scissors. Aseptic precautions should be observed.

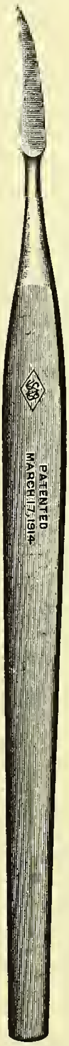


Fig. 836. Lancet or bistoury.

PRESERVATION OF THE TEMPORARY TEETH

Since the temporary teeth are designed by nature to perform certain definite and important functions, it is necessary to use every effort to retain them in a healthy condition until the time arrives for their replacement by the permanent denture. The chief reasons for their preservation are:

1. To prevent bad habits of mastication, with their evil consequences.
2. To assist in the growth of the jaws; and
3. To avoid irregularities of the permanent set.

If decay is allowed to form and remain untreated, or if the operation of extraction is performed, the functions of mastication are interfered with. The little patient soon learns to avoid chewing on sensitive surfaces, or is unable to properly masticate where spaces are left from extraction, with the result that the habit of bolting the food may early be acquired, which may be very hard to overcome and in many instances may cling throughout life. Following this, digestive and intestinal disturbances are likely to arise, which will interfere with proper physical development and be a menace to health in later years. Early extraction of deciduous teeth allows a closing in of the adjoining teeth and a slowing up of the growth and development of bone in that area, with the result that the enlargement of the jaw to make room for the permanent successors is retarded and crowding results. Irregularities thus supervene which will necessitate in many instances the services of the orthodontist. Under normal conditions, the child should show a beginning separation of the temporary teeth at the age of three years. This is the result of bone enlargement and expansion to make room for the incoming permanent teeth.

RELIEF OF PAIN WITH PALLIATIVE DRESSINGS

Unfortunately, in many cases, the first visit of the child to the dentist is for the relief of pain. In these cases, temporary dressings must often be quickly and skillfully placed to relieve tooth-ache (odontalgia). Usually as little cutting as possible should be done. Some of the soft decay may be scooped out of the cavity with a small spoon excavator and a dressing of oil of cloves, eugenol, phenol compound (Buckley) or camphophenique applied. In some instances, sealing the cavity may be inadvisable owing to timidity or restlessness of the little patient. In these cases, Fletcher's carbolized resin may sometimes be placed in position on a small pledget of cotton without sealing, until the next visit. The formula of this preparation is:

Phenol	ʒi (4.0 cc.)
Resin (colophony)	ʒi (4.0 Gm.)
Chloroform	℥ss (16.0 cc.)—Misce.

On evaporation of the chloroform, the resin assists in hardening and maintaining the cotton dressing in position in the cavity. For hygienic reasons, one or the other of the previously mentioned agents should be sealed into place if possible.

CAVITY PREPARATION, STERILIZATION AND FILLING

The length of sittings should vary, depending on the age, intelligence, physical condition and cooperation of the child. For very young children, the length of the visit should not exceed more than ten or fifteen minutes, as an average. For children under nine or ten years of age, the operation should usually be confined to thirty minutes if possible, while from three quarters to one hour should be the limit for patients between ten or twelve and fifteen or sixteen years of age. Fig. 837.

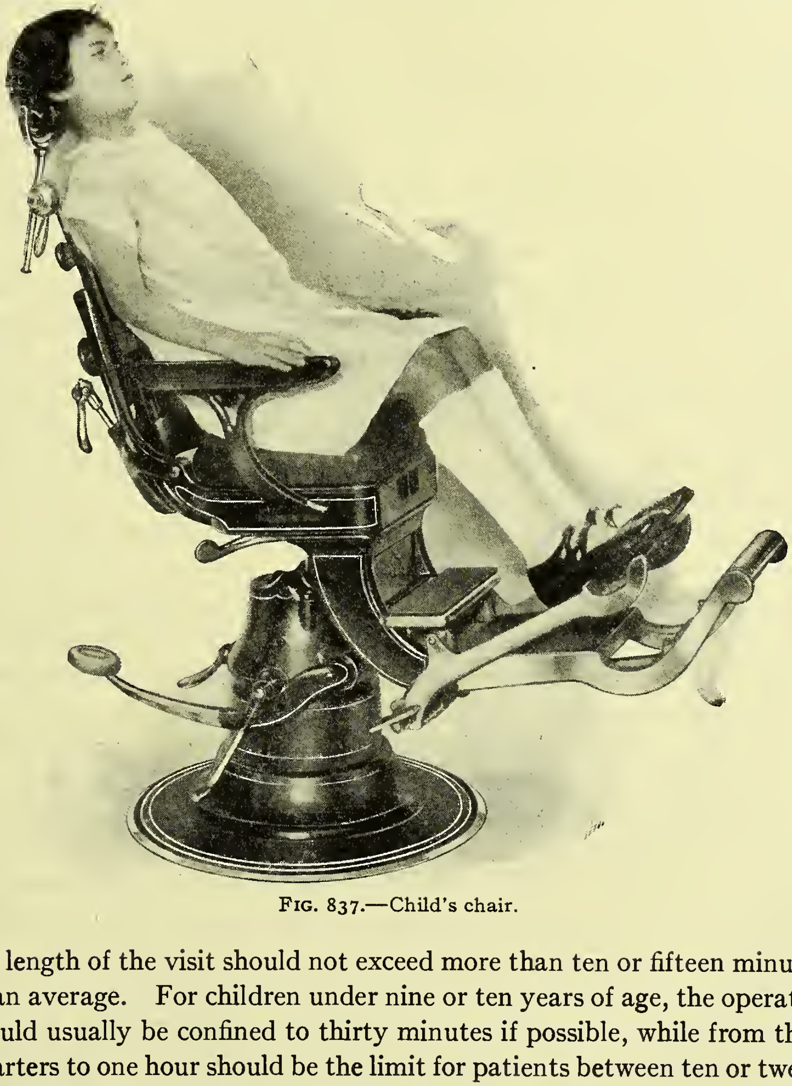


FIG. 837.—Child's chair.

The comparatively large size of the pulp chamber and its close proximity to the surface in deciduous and young permanent teeth should be constantly borne in mind in performing operations for these types of patients. The danger of pulp exposure or cutting into the recessional lines of the pulp is ever present. Cavity preparations must be performed as well as conditions will admit. In many instances, complete removal of decay is inadvisable or impossible on temporary teeth.

In cases of proximal surface decay on these teeth, the decayed area may sometimes be partially or completely disked or filed away after the method of G. V. Black,[3] treated with ammoniacal silver nitrate (Howe) and left unfilled. In cases of this nature, the surface should be disked or filed well toward the lingual surface, as far as possible, and an attempt made to leave a portion of the proximal surface in the gingival third near the labial or buccal aspect, to prevent drifting together of the proximating teeth. The resulting discoloration will be objectionable but will often have to be countenanced.

It often is necessary to leave a layer of partially decalcified dentin on the walls of cavities in children's teeth, to avoid unnecessary pain, as well as exposure of the pulp. In these cases, silver nitrate may be applied as a desensitizing and sterilizing agent with advantage. The application of ammoniacal silver nitrate and its deposition with eugenol by the Howe method, as used in the Forsyth Infirmary, is advised. Other methods of application are as follows:

1. Touch a solution of silver nitrate, 40%, to the dried surface with a pointed orange-wood stick.
2. Saturate blotting paper or asbestos felt, preferably the latter, with the solution, place in position with dressing pliers and fill the cavity.
3. Carry a few granules of silver nitrate to place on heated gutta-percha, filling the cavity with the latter substance.
4. Dip a silver wire in nitric acid and touch to the walls of the cavity, thus depositing silver nitrate in the area of decay.
5. Touch the affected surface with a small stick of lunar caustic.

Whatever method is used will likely cause discoloration of tooth structure, which should be avoided on permanent anterior teeth. In the use of all of these latter methods, exposure of the cavity to sunlight is advisable to produce the full effect of the silver salt.

Many timid children will rebel against the use of the rubber dam and in these cases its application should not be attempted. It will, however, be found on trial that most young patients will submit to it without trouble and often will prefer it to absorbents. When used, most of the excavation should be completed before its application, in order not to tire very young patients. Clamps should be avoided in most instances, depending on the use of ligatures where necessary.

Filling Cavities for Children.—For filling purposes, oxyphosphate of zinc and copper cement, guttapercha and amalgam are indicated in the deciduous teeth. Most operations in these teeth, owing to the age of the patient, small size of the mouth, necessity of imperfect cavity preparation and other procedures, as well as the difficulty of maintaining dryness, can be of a temporary nature only, and parents should be informed of this fact. Frequent inspection and refilling may be necessary. Wherever possible amalgam should be the material of choice in filling the temporary molars, on account of its lasting qualities and its ability to maintain proximal contours and contact points.

Interproximal guttapercha fillings, bridged across two adjoining cavities may sometimes be advisable as a temporary expedient in very young patients. Injury to the gum tissue, from packing of the material against it during its insertion, or from the force of mastication must be avoided. This may be prevented by the use of metal space guards or concavo-convex discs, prepared by the operator from gold, or German silver, coated on their under surface with guttapercha and adapted to the gingival walls of the two cavities, thus bridging across the space, after which the filling may be inserted *en masse.* Cement or amalgam never should be used in this manner on account of their lack of elasticity.

Copper cement in anterior temporary teeth is often indicated. Its advantages and disadvantages are practically the same as those previously mentioned for permanent teeth. It possesses the property of being a preservative of tooth structure, owing to its antiseptic qualities. It has the disadvantage of being black or red in color, unless some of the light copper cements are used, which latter are of doubtful value.

Whenever ideal cavity preparation may be obtained, its color will not be objectionable, dryness may be maintained for a sufficient length of time for its introduction, proper contours may be accomplished and proximity of the pulp is not prohibitive, amalgam should be used. Under these conditions, it is the more lasting material. It should, however, never be bridged across two adjoining cavities.

In the selection of filling materials for the permanent teeth of children, every case will be a law unto itself and will have to be handled with good judgment. As a general rule, cement for the anterior teeth and amalgam for the posterior ones are indicated, until the child reaches an age where the roots of the teeth are fully formed, and where physical and mental development will allow gold building operations. Inlay work occasionally may be resorted to in badly broken-down cases, even in quite young patients. Pre-carious pits and fissures should be early sought and the operation of prophylactic odontotomy performed where indicated.

PULP DISTURBANCES

In cases of exposure of vital or the presence of putrescent pulps, the condition as to development or absorption of the roots of the temporary teeth, as revealed by the X-ray, must determine the procedures advisable. If the time is near for eruption of the permanent successors, the tooth had better be extracted at once. If several years must elapse before this period arrives, attempts should be made to maintain the tooth in its position in the arch. In favorable vital cases, capping the pulp may be attempted. In others, devitalization or anesthetization of the pulp, its removal and filling of the canals, will be indicated. Attempts to fill imperfectly developed or partially absorbed roots will often result in failure. Individual cases must be closely studied and judgment exercised, based on age, physical condition, value of the tooth involved and state of development or absorption of its root, as to whether conservation or extraction is advisable.

Applications of phenol or creosote, sealed into the cavity, are recommended for slow devitalization of pulps, where pulp removal has been determined upon. In putrescent cases these agents or formo-cresol may be used. In either instance, the pulp chamber and canals are later opened and filled. In the majority of cases, abscessed temporary teeth had better be extracted at once, on account of the difficulties of treatment and the danger of focal infection and injury to the enamel organ of the succeeding permanent tooth. However, occasionally in favorable cases in the mouths of older children, whose mental and physical development are well advanced, treatment and filling of the canals may be attempted.

The Treatment of Alveolar Abscess in temporary teeth is practically the same as for putrescent teeth, as far as conditions permit. If the tooth is very tender, the passage of a broach into the canals, after flushing out the cavity, often will afford exit for malodorous gases and other products of putrefactive decomposition, and relieve the acute symptoms. Lancing of the gum is practiced where swelling and involvement of the peridental tissues is present, and often affords quick relief from pain. As soon as conditions will allow, the chamber and canals may be opened and the usual treatments for putrescent pulp applied, these cases often responding much more readily than permanent teeth. Figs. 838 and 839.

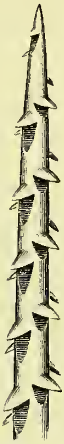


FIG. 838. Pulp canal cleanser (much enlarged).

FIG. 839. Pulp canal cleansers (barbed broaches).

FILLING PULP CANALS

Usually the materials indicated for filling canals of temporary teeth are those which will be absorbed or dissolved with the absorption of the root. The following are recommended by various authorities:

1. Salol. Liquefy by heat and pump into the canals with a warm smooth broach.
2. Paraffin, melted and pumped into the canals.
3. Salol and aristol, equal parts, used in the same manner.
4. Salol, aristol and paraffin, using the same method.
5. Zinc oxid, or thymolized calcium phosphate made into a paste with oil of cloves, eugenol, or formocresol, and carried in on a smooth broach.
6. Euca-percha (Buckley).
7. Dentinoid (Buckley).
8. Alum, thymol and glycerine, equal parts, made into a paste and carried into the canals on a smooth broach.

OPERATIVE DENTISTRY FOR OTHER SPECIAL TYPES

In the management of ordinary or average types of patients, the operative procedures, as described in previous chapters, are usually indicated. However, it must be understood that these are ideal technics, subject to modification, depending on circumstances. Many important factors which may modify the selection of filling materials or the extension of cavity walls have been mentioned in a discussion of these subjects. It is now understood that in handling children, ideal conditions or results often cannot be obtained and that frequently operative procedures have to be modified to meet the needs of such individual cases. This is equally true in the management of the types of patients now to be described.

PUBERTY, ADOLESCENCE, THE MENOPAUSE AND OLD AGE

In the majority of cases, boys and girls pass through the period of puberty and adolescence with very little, if any inconvenience or disturbance. In many instances, however, these are times of special physical and mental strain; in fact, they are often crucial periods, especially with girls. Under these circumstances, the patient may appear pale and anemic, present evidences of lowered vitality, become irritable, careless, weak, with general symptoms of nervousness, anorexia, sleeplessness, and even chorea. Frequently there is exhibited great fear of the dentist and dental operations, and consequently they should be treated with consideration and special care. Often cavity preparation will have to be modified, avoiding extension of cavity margins, operations calling for stamina and those placing the patient under undue stress. With many, gold building operations will be contra-indicated and dental ministrations requiring long sittings should be avoided. Sometimes only work of a temporary nature should be attempted, and the plastic filling materials selected, tiding the patient over this period of special stress until physical maturity has been established. Habits of mastication and the type of diet should be investigated and corrected, if necessary. The beginning of puberty, in temperate climates averages in girls from 12 to 14 and in boys from 13 to 16 years, while adolescence or growth extends from that time until adult life. In tropical climates, puberty often begins and maturity arrives much earlier.

Women passing through the menopause often present similar symptoms of physical, nervous and mental stress and must receive the same careful consideration. With the aged, all of the functions of the body are lowered and vital resistance below par, consequently they will have to be treated with great sympathy, care and understanding, and operations modified accordingly.

PREGNANT AND LACTATING WOMEN

Some women pass through the period of pregnancy with very little dental disturbance. In many instances, however, there is increased tendency to oral disease. These patients often complain of pain about the teeth, which may be due to oral disturbance needing attention, or to reflex nerve irritation for which no definite local cause can be found. The increased tendency to caries and gingival irritation often is marked. Figs. 840 and 841. This may be attributed to several causes, such as (1) loss of interest in and lack of care of the teeth and soft tissues of the mouth; (2) acid vomitus of morning sickness, brought in frequent contact with the oral tissues; (3) general lowering of the vitality and resistance of all the tissues of the body including the masticating machine, from improper maintenance of hygienic and health standards; (4) lack of proper diet for the maintenance of health, bony and dental tissues of the mother and for the building of similar tissues for her offspring; and finally (5) appropriation of calcium and phosphorus from the bones and teeth of the mother by the growing fetus, in the latter instances. Recent literature is teeming with discussions and reports of researches conducted to determine the answer to the long-propounded question as to whether the bones and teeth of the mother are derprived of their mineral salts for the building of similar structures of the offspring, during the periods of pregnancy and lactation. A digest of these recent reports confirms former beliefs that with proper diet and maintenance of high health standards on the part of the mother, sufficient calcium and phosphorous are supplied via the blood streams to take care of the normal needs of the offspring for these substances, both during pregnancy and lactation; but

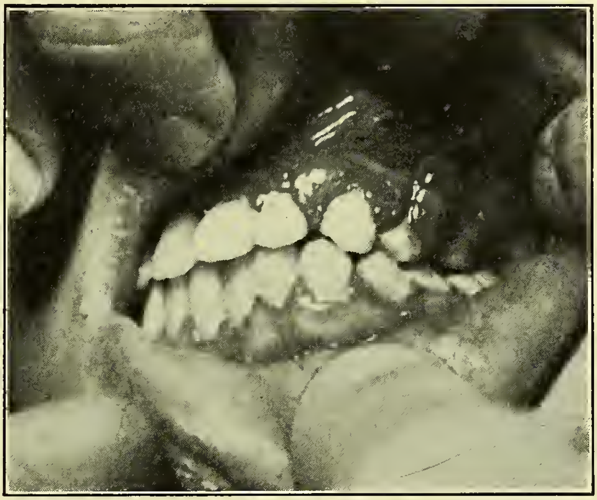


FIG. 840.—Gingivitis of pregnancy.

that with calcium and phosphorous imbalance the offspring will appropriate mineral salts from the maternal hard tissues, for its own benefit and upbuilding.

During these periods, early and frequent examinations, sometimes monthly, of the mouth should be instituted, and preventive and restorative measures carefully inaugurated. Frequent prophylactic treatments should be given and cavities should be sedulously sought and filled in their incipiency. Although the patient is usually under the supervision of the obstetrician or pediatrician, the importance of correct diet, maintenance of high health standards and hygienic conditions throughout pregnancy and lactation should be stressed by the dentist. Their bearing on the oral health of the mother and on the development of a high and resistant type of denture of the child should be fully discussed. In the early stages of pregnancy the highest type of dental service may often be rendered without deleterious effect. In the later stages, short sittings and temporary operations will frequently be necessary. Major dental operations involving great stress, such as extractions, administration of anesthetics, etc., should be performed only after consultation with and consent of the physician in attendance, on account of the danger of miscarriage or abortion with the attendant possibility of medico-legal complications and suits for malpractice.

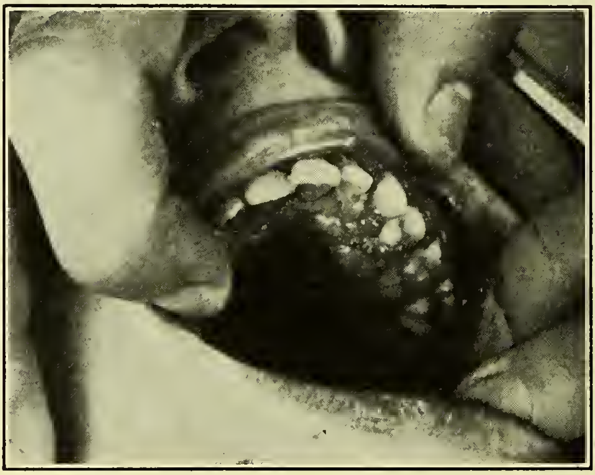


FIG. 841.—Edematous gingivitis of pregnancy.

NEURASTHENICS AND NEUROTICS

These patients exhibit symptoms of nervous exhaustion and low physical and nervous reserve force. Often nervous irritability, or excitability, apprehension, anorexia, insomnia, melancholy, and fear are readily apparent. Indefinite neuralgic disturbances and neuritis are sometimes manifested. In neurasthenics a disturbance of occlusal balance needing correction is occasionally seen. Often they complain of very sensitive teeth. Sometimes this is the result of fear, apprehension of dental operations and general nervousness. In many cases, hypersensitivity of the dental tissues is actually present, due to an over-organized and highly developed or irritated nervous system, with exhibition of severe reactions to minor disturbances or causes. This must be recognized and treated accordingly. It is now believed that many cases of neurasthenia are due to hypoadrenia.

These types must be handled with great patience, tact, gentleness, and yet, withall, with great firmness. The mind of the operator must diplomatically dominate that of the patient. In many instances, short sittings, use of remedies for relief of pain, modified cavity preparations, temporary operations and plastic filling materials will be the rule. In other cases, depending on circumstances, the psychologic effect of implanting in the mind of the patient a feeling of confidence in the ability of the operator and a realization of his sympathetic interest, will often produce remarkable results.

INVALIDS, CONVALESCENTS AND THE BED-RIDDEN

With invalids and convalescents, the same psychologic measures and modified types of procedure will often have to be adopted as mentioned for the previous cases. Bed-ridden patients are most often seen in hospitals or institutions, where they will be handled by the dental interne. Occasionally, the dentist will be called upon to render service at the home of the afflicted. Many of these cases are most trying, calling for all the humanitarianism, ingenuity and skill of the professional man. If he is correctly imbued with the professional spirit, he will unhesitatingly respond to the call for service. Chronic invalids are frequently handled best and if the dentist is familiar with the technic of hand instrumentation, much may frequently be done for them in the way of restorative operations. Many hospitals and institutions are now provided with proper facilities for dental service to sick patients, and under these circumstances much may be accomplished. With chronic cases, strict attention to oral cleanliness, through the usual oral hygienic measures and prophylactic procedures should be insisted on.

Patients suffering with acute illnesses or diseases at home will often call on the dentist for relief of pain. The lowered resistance and vitality of the patient often promote slow response to, or recovery from dental ministrations, and favor the production of focal infections. In treating these cases, the patient should be propped up on pillows and placed in as favorable a position as possible, to obtain proper light and access. The assistance of the nurse or attendant is important. Consultation with the attending physician will often be advisable or necessary for the benefit of the patient, to obtain information as to the bearing of systemic conditions on the case and as a matter of legal protection to the dentist, in case of an unfavorable outcome. Following an examination, washing of the mouth or spraying with a DeVilbis spray bottle or syringe carrying an antiseptic solution will often be indicated. Gentle removal with a spoon excavator of decay from a cavity and the application of an antiseptic, sedative dressing may be required. The condition of the patient may not admit of much cutting or of sealing of the cavity. In these cases, the nurse or attendant may sometimes be given a pair of dressing plyers, absorbent cotton and a mild sedative remedy, with instructions as to occasional application. The nurse may also be instructed as to the regular care of the mouth with an antiseptic solution and other measures. Other cases may permit more vigorous or effective measures on the part of the dentist. Counter-irritation or lancing of the soft tissues, or the opening of a cavity to admit the escape of gases in cases of putrefactive decomposition of the pulp or alveolar abscess may sometimes be required. In acute illnesses, extraction of teeth would usually be attempted only in cases of necessity, after consultation with the attending physician. Each case must be handled with judgment and discretion, depending on the conditions present and the cause and nature of the disturbance.

Bibliography

1. Stellwagen, T. C., Editor,—Coleman, Alfred: "Manual of Dental Surgery and Pathology," Lea's Sons, Philadelphia, 1882.
2. Black, G. V.: "Operative Dentistry," 6th ed., vol. 2.

Gompertz, Jewell M.: Factors that influence mouth conditions during pregnancy, Jour. Dental Research, vol. VI, no. 4, Dec. 1924, p. 473.

Schultz, Fred. W.: Preventive dentistry from the standpoint of the pediatrician, Jour. Amer. Dent. Assoc., vol. XV, no. 12, Dec. 1928, p. 2311.

Adair, Fred L.: Prenatal care and diet, Jour. Amer. Dent. Assoc., vol. XV, no. 12, Dec. 1928, p. 2319.

Taverud, Guttorn: Influence of pregnancy on teeth, Jour. Amer. Dent. Assoc., vol. LXIX, no. 12, Dec. 1927, p. 1213.

Simpson, Clarence O.: Radiographic diagnosis of difficult dentition, Jour. Amer. Dent. Assoc., July 1927, p. 1171.

Moore, W. D. N.: The first permanent molars, Jour. Amer. Dent. Assoc., July 1927, p. 1213.

Stine, Carvin F.: Filling materials and their indication in preservation of children's teeth, Jour. Amer. Dent. Assoc., Nov. 1929, p. 2118.

Barker, Paul A.: Conservation of children's teeth, Jour. Amer. Dent. Assoc., Feb. 1927, p. 298.

Nodine, Alonzo M.: Treatment of teeth of sick patients, Amer. Dent. Surgeon, Nov. 1923, p. 487.

Cattell, Psyche: Eruption and growth of permanent teeth, Jour. Dental Research, Apr. 1928, p. 279.

Weeks, Haidee: Clinical conditions in the child's mouth, Jour. Amer. Dent. Assoc., Aug. 1928, p. 1445.

Jordan, M. Evangeline: What shall be done with dead and dying pulps?, Dental Survey, June 1929, p. 20.

Logan, W. H. G. and Kronfeld, R.: Development of human jaws and surrounding structures from birth to age of fifteen years, Jr. A.D.A., vol. 20, no. 3, March 1933, p. 379.

McBeath, E. C.: New concept of development and calcification of teeth, Jr. A.D.A., April 1936, p. 675.

CHAPTER XXVI

DISEASES OF THE DENTAL PULP

GENERAL CONSIDERATIONS—CLASSIFICATION—CAUSES—SYMPTOMS—DIAGNOSIS AND TREATMENT OF VITAL PULPS

No attempt is made in this work to enter into an extended discussion of the causes and histo-pathology of diseases of the pulp, these considerations being more appropriately confined to texts on dental pathology. It is, however, necessary for an intelligent study of pulp canal therapy and filling, to briefly review the more important phases of the subject. The therapeutic treatment of these diseases is discussed, although lying more appropriately within the province of works on dental therapeutics. The various technical and operative procedures incident to removal of the pulp and filling of the pulp canals receive due attention, and a detailed description of them is offered in the final chapter.

GENERAL CONSIDERATIONS

The pulp is situated in the pulp chamber and canals, and sends out from its odontoblastic layer numerous prolongations, the dentinal fibrillae, these penetrating the dentin to the dento-enamel junction, and in some cases even entering the enamel. The enamel is a low conductor and, under normal conditions, acts as a protective covering to the pulp and the dentinal fibrillae, preventing the contact with irritating chemical substances and lessening the transmission of heat, cold and electricity. When the enamel is intact and the pulp healthy, the tooth is not sensitive to ordinary variations in temperature, the application of a very mild electric current, or the presence of the chemical substances frequently found in the mouth (salts, sweets and acids). If, however, through the action of caries or other pathologic disturbances, the enamel be lost and the dentinal fibrillae be subjected to the action of these agents, they soon become abnormally responsive to them, transmitting the sensations to the nerves of the pulp, which soon become over-stimulated and irritated, resulting in pathologic conditions of its substance. Figs. 842, 843 and 844.

From a pathologic standpoint, diseases of the pulp are usually primarily affections of its vascular system, due to over-stimulation of

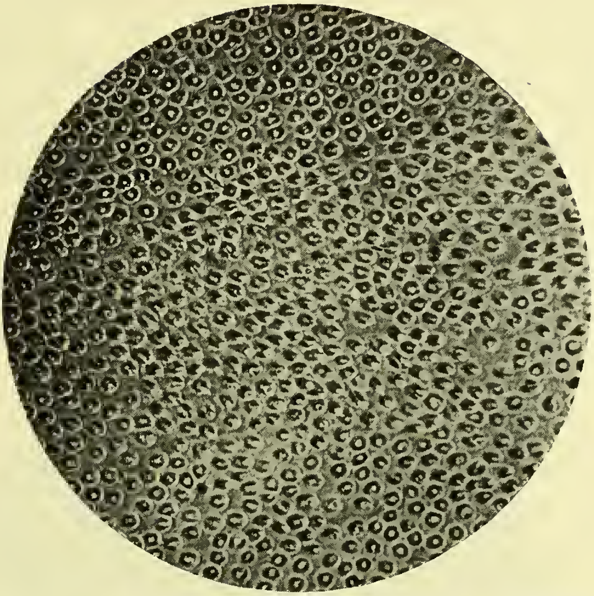


FIG. 842.—Dentinal tubules surrounded by sheaths of Neuman. (Courtesy of Dr. Harold K. Box.)

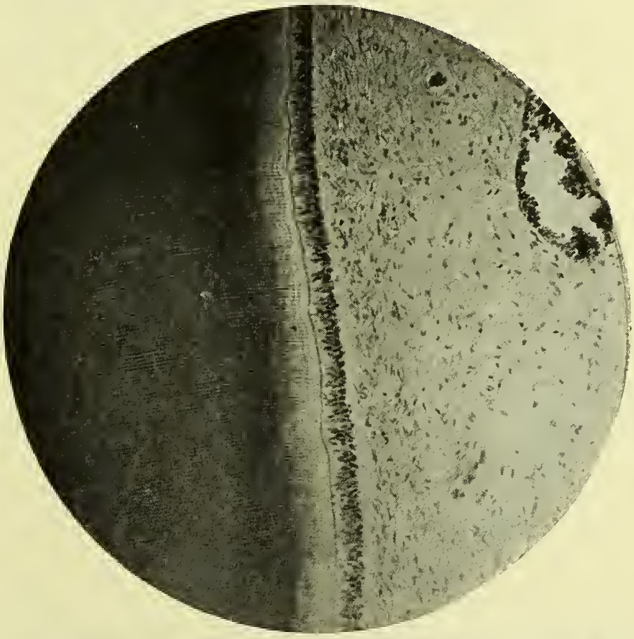


FIG. 843.—Odontoblasts in the center, dentin to the left and main pulp tissue to the right. (Courtesy of Dr. Harold K. Box.)

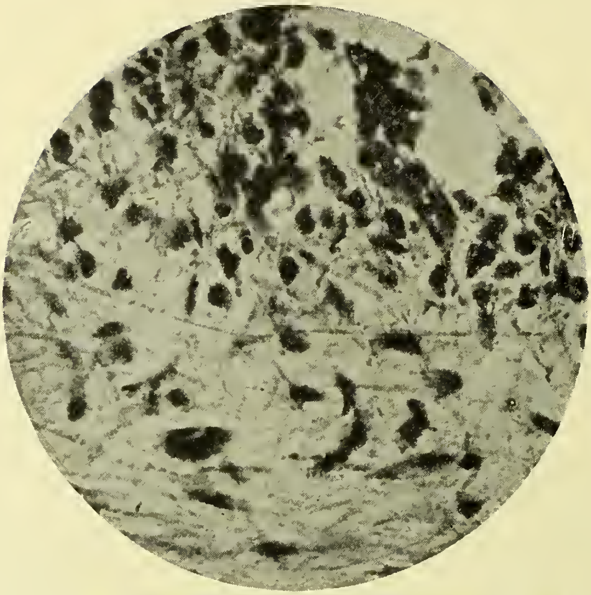


FIG. 844.—Neuro-fibrillar arborizations beneath the odontoblasts of the pulp. (Courtesy of Dr. Harold K. Box.)

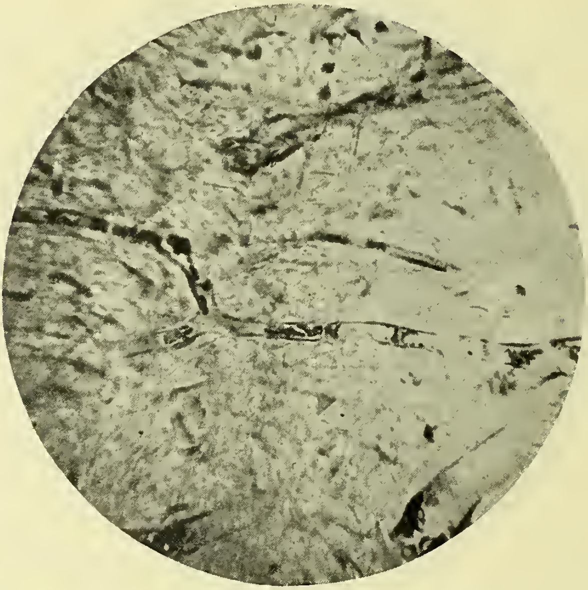


FIG. 845.—Capillaries on the periphery of the pulp. (Courtesy of Dr. Harold K. Box.)

the sensory and vasomotor nerves of the part. They are also largely progressive in character. If the primary causes mentioned in the preceding paragraph receive early treatment, the resultant fullness in the arteries of the pulp (arterial hyperemia) be relieved, and the lost enamel and dentin be compensated for by the application of a non-conducting filling, or other appropriate measures, the pulp usually may be permanently restored to its normal state. If, however, the above conditions are of an acute nature and are allowed to continue untreated, the increased supply of blood in the arterial system of the pulp becomes dammed back into the veins of the part and venous hyperemia results, with the escape through the vessel walls of the lymph and red corpuscles. This condition supervening finally results, on account of internal pressure, loss of tone and consequent rupture of the vessels, in the passage of the red and white corpuscles and platelets into the interstices of the pulp tissue, so that a condition of inflammation is established. When venous-hyperemia or inflammation is present, the only alternative is the anesthetization and removal of the pulp. Figs. 845 and 846.

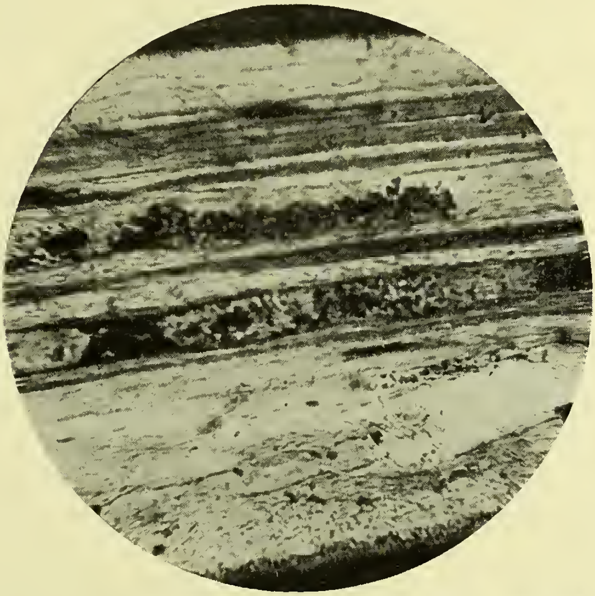


FIG. 846.—Artery and vein in the pulp. (Courtesy of Dr. Harold K. Box.)

If these conditions be still further neglected, and remain untreated, pus-forming micro-organisms, constantly present in the mouth and in the blood streams of the body, make their entrance into the pulp tissue or are already present, with the result that pus formation occurs (suppuration); or the death of the pulp is finally accomplished through the process of putrefaction from the action of putrefactive germs, with the formation of malodorous gases (putrefactive decomposition, or moist gangrene). If, however, suppurative or putrefactive germs do not enter, the pulp will die a natural death from lack of nourishment (its blood supply being interfered with or cut off), and the condition of dry gangrene is established. In all of these disturbances there is always the possibility of the pathologic condition extending through the apical foramina, with the resultant production of disease processes in the tissues of the apical space and, if germs be present, the formation of an alveolodental abscess, (Septic apical pericementitis), or a granuloma.

The acute diseases of the pulp mentioned above are progressive in character and may now be briefly described as follows:

1. *Arterial Hyperemia.*—An increased supply of blood in the capillaries, arterioles, and arteries of the pulp, resulting in overfullness and distention of these vessels, with consequent pressure on the sensory nerves of the part, and resultant pain.

2. *Venous Hyperemia.*—The blood becomes dammed back into the veins, with the production of the same condition in these vessels, increased pain from pressure and the passage of lymph and red blood corpuscles into the interstices of the pulp.

3. *Inflammation* (Pulpitis).—The pressure in veins and arteries results in their rupture and, in addition to the preceding complications, the passage of the white corpuscles through their walls into the interstices of the pulp, resulting in the tissue changes characteristic of inflammation in other parts.

4. *Suppuration* (Suppurative Pulpitis).—The blood corpuscles and the surrounding pulp tissue are broken down, liquefied and transformed into pus, through the action of suppurative germs, which have entered by way of the blood stream, carious cavities, defective pits and fissures, cracks in the enamel, exposed dentinal surfaces from erosion, abrasion or receded gingivae.

5. *Moist Gangrene* (Putrefaction).—The blood current becomes stagnant and finally ceases, on account of mutual pressure of the vessels passing through the minute apical foramina. Death of the tissues occurs from lack of nourishment, putrefactive decomposition and destruction resulting from the action of putrefactive germs, with the formation of malodorous gases and highly-infective, irritating products.

6. *Dry Gangrene.*—In some instances, germs do not enter, death of the tissues occurring without suppuration or putrefaction, from

strangulation, resultant stasis and lack of nourishment. The pulp remains in a hard, dry, shrivelled, insensitive condition.

7. *Alveolar (Periapical) Abscess and Its Sequellae.*—The putrescent material infects the tissues of the apical space, with resultant pus formation, breaking down and destruction of these parts.

The above is a brief description of the usual progress and termination of the *acute* diseases of the dental pulp. It will be observed that they are primarily destructive in character. In some instances the causes are of such a low degree of activity and virulence that *chronic*, low grade irritation and inflammation of the tissues may supervene. In addition, infection may be absent or of low virulence. As a result, certain constructive, protective pulp reactions may occur in the form of calcification of the dentinal tubules, secondary dentin formations on the walls of pulp chamber and canals, pulp nodules or calcareous degeneration within the pulp substance. In other instances, low grade, long continued, chronic inflammation without formation of calcareous material may arise. Or instead, the pulp being essentially a delicate tissue, may become subject to the various forms of degeneration, as seen in other tissues of the body, such as sclerosis, fibrosis, fatty, hyaline, mucoid, colloid and nerve-end degenerations. Neoplasms have also been discovered in the pulp. Although the constructive or building up processes

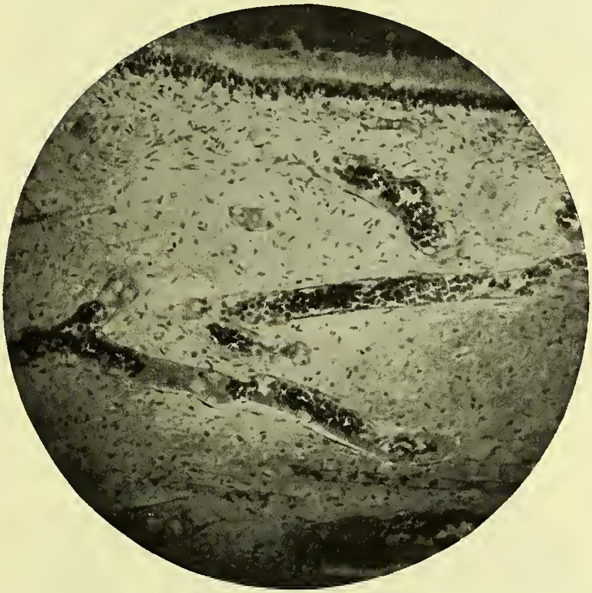


Fig. 847.—Hyperemia of the pulp. (Courtesy of Dr. Harold K. Box.)

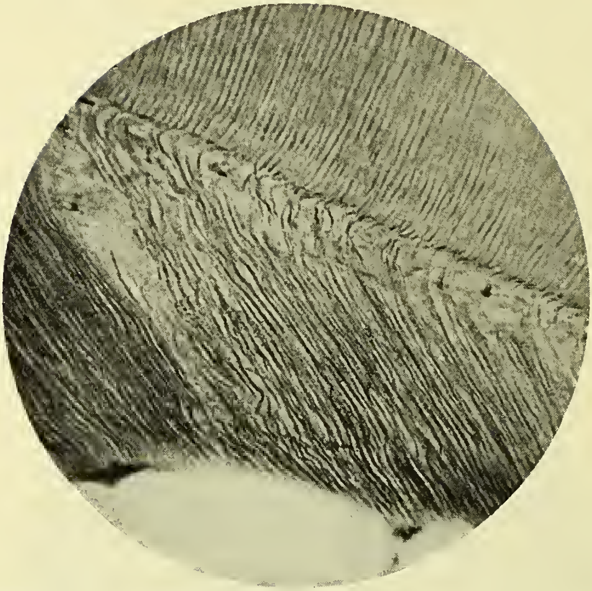


FIG. 848.—True secondary dentin. (Courtesy of Dr. Harold K. Box.)

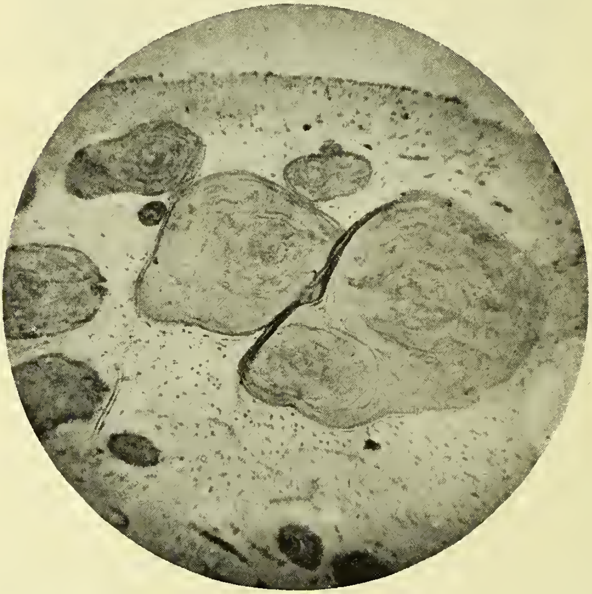


FIG. 849 —Smooth pulp nodules. (Courtesy of Dr. Harold K. Box.)

mentioned often arise, all of the diseases of the pulp, including both the acute and chronic forms ultimately result in degeneration and death of its substance. Figs. 847, 848 and 849.

The *chronic* diseases of the pulp may now be mentioned as follows:

1. Tubular calcification.
2. Secondary Dentin.
3. Pulp Nodules.
4. Chronic Inflammation (Pulpitis).
5. Calcareous Degeneration.
6. Fibroid and other forms of Degeneration.
7. Neoplasm.
8. Pulp with periapical complications (Granuloma, etc.)

A classification of pulp disturbances, based on the previous discussion, is now presented as follows:

CLASSIFICATION OF DISEASES OF THE PULP

I. Acute Diseases

A. *Vital Pulps*

1. Arterial Hyperemia: Pulps frequently capable of being restored to a normal condition.

2. Venous Hyperemia: Pulps incapable of being restored to normal condition.

3. Pulpitis (inflammation): Pulps incapable of being restored to normal condition.

4. Suppuration: Pulps incapable of being restored to normal condition.

    (*a*) Abscess
    (*b*) Ulceration

B. *Non-Vital Pulps*

5. Moist Gangrene (Putrescent pulp)
6. Dry Gangrene (Non-putrescent)
7. Pulps with periapical complications (Periapical Abscesses, etc.).

II. Chronic Diseases

1. Tubular Calcification
2. Secondary Dentin (adventitious dentin)
3. Pulp Nodules (pulp stones)
4. Pulpitis (chronic inflammation)
5. Calcareous Degeneration

6. Fibroid and other forms of Degeneration
7. Neoplasms
8. Pulps with chronic periapical complications (Granuloma, etc.).

Pulps affected with arterial hyperemia may with proper treatment often be restored to normality. Presence of most of the other pathologic disturbances mentioned indicates removal of the pulp, while pulps suffering with periapical complications will have to be removed or the tooth extracted, depending on conditions to be later described. Although it is claimed that resolution and healing occasionally occurs in venous hyperemia and pulpitis, it is of such rare occurrence that its possibility should not be considered, but pulp removal restorted to. Suppuration, gangrene, both moist and dry, and calcareous degeneration all indicate pulp removal. Tubular calcification and secondary dentin may be interpreted as nature's defense against attacking agencies and do not under ordinary conditions necessitate removal of the pulp. Pulp nodules and the degenerations may be considered a menace, indicating marked pathologic disturbances and are usually an indication for removal of the pulp. Neoplasms of the pulp are of interest only to the histo-pathologist and cannot be diagnosed clinically. Bacteriologists have discovered the presence of germs in apparently normal vital pulps which have given no clinical evidence of infection or pathologic disturbance. Since germs are present in the air, drinking water, foods, the oral and other cavities, the blood streams and tissues of the body, it is but natural that they should be found in the vital tooth pulp. Their presence there is of no pathologic significance as long as the normal resistive powers of the body are maintained and the usual causes of pulp disturbance are held in abeyance.

ETIOLOGY OF PULP DISEASES

The causes leading to pathologic disturbances of the pulp may be of local or systemic origin. Of the local causes, five distinct types may be distinguished, namely, (1) thermal shock, (2) chemical irritation, (3) traumatic injury, (4) electrical phenomena, and (5) extension via the blood stream or reflexly from other areas. The systemic causes are concerned with certain constitutional disturbances lowering the resistive powers of the body, changing the vascular tension in the parts or acting reflexly.

LOCAL CAUSES

Thermal Shock.—These causes often act as a result of loss of the enamel, the normal protective covering, through the process of caries, erosion, abrasion, receded gum, exposure of the dentin and cementum at the neck of the tooth, and similar disturbances. The placing of metallic fillings in too close proximity to the pulp, without the use of a non-conducting intermediate, heat production as the result of friction incident to the careless use of rough disks and stones in grinding and polishing operations are frequent causes. As a result, undue thermal changes are transmitted to the pulp, leading to exalted response, irritation and vascular congestion. Fig. 850.

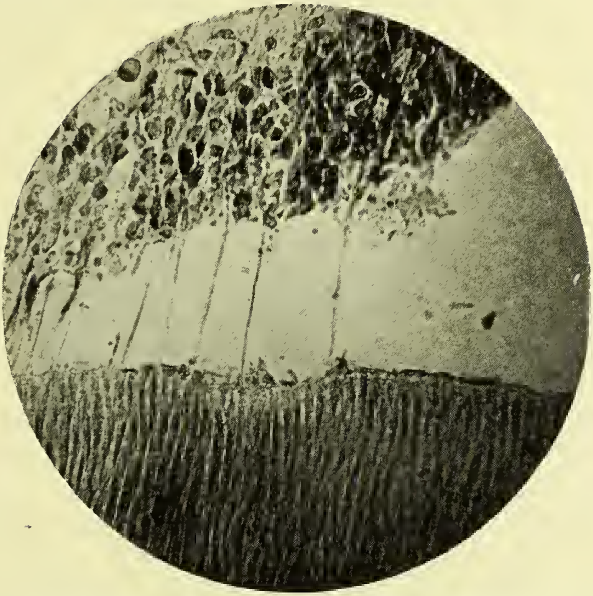


FIG. 850.—Dentinal fibrils stretching from the odontoblasts above into the dentinal tubules below. The pulp has been torn away from the surface of the dentin. (Courtesy of Dr. Harold K. Box.)

Chemical Irritation.—Irritation and stimulation of the dentinal fibrils from septic dentin left under fillings, leaky fillings allowing the entrance of saliva and germs, imperfect drying and exclusion of saliva from the field of operation through non-use of the rubber dam, septic cement under crowns and leaky fillings, and the presence of food masses in open cavities may be mentioned as frequent causes under this heading. In these cases, the germs or their toxins may often pass through the dentinal tubules into the pulp tissue and directly produce irritation, inflammation and infection of pulpal tissues, even in the absence of direct exposure of the pulp. Under these circumstances, infection of the pulp is undoubtedly present in many cases of hyperemia or inflammation without exposure. As previously mentioned, germs may be present in the vital and apparently normal pulp, having entered by way of the circulation, under caries or fillings, on exposed dentinal surfaces at the necks of teeth, on abraded or eroded areas or in the location of defective pits and fissures and cracks in the enamel. Sugar, acid or any salts, when applied to exposed dentinal surfaces will often produce severe reactions in the pulp. Continued contact of the saliva with exposed dentinal or cemental surfaces at the necks of teeth suffering from receded gums, or in improperly sealed cavities prepared for the reception of inlays or fillings may produce hyperemia and inflammation of the pulp, as well as hypersensitive dentin. In some instances, the condition may result from hypertension of the liquid contents of the dentinal tubules; in others to chemical irritation from the saliva. Caustic and irritating drugs, such as zinc chlorid, trichloracetic acid, formalin and silver nitrate used in too close proximity to the pulp may act as chemical irritants and be productive of marked pulp reactions and pathologic disturbances. The same may be said of oxychlorid, oxyphosphate and silicate cements, and agents used in pulp capping operations.

Traumatic Injury.—Among causes of this nature may be mentioned careless cutting or grinding of the exposed ends of the dentinal tubules during cavity preparation and similar operative procedures, blows on the teeth, thread-biting, or ice-cracking, over-malleting of fillings, excessive occlusion of fillings and crowns, and traumatic occlusion from any condition producing it. The first of these causes acts directly on the tissues of the pulp via the dentinal fibrillae, while the others mentioned first produce their effects on the peridental membrane and periapical tissues, following which hyperemia and inflammation of the pulp may occur from extension from these areas via the circulation to the tissues of the pulp.

Electrical Phenomena.—Both static and galvanic currents may affect the pulp tissues. Occasionally the touching of a large metallic filling with an instrument produces a sharp pain in the pulp. The difference in electric potential between the instrument in the hands of the operator and the metal of the filling is responsible, as a result of which a charge of static electricity passes to the pulp and produces irritation. Galvanic currents are occasionally produced in the mouth from the too close proximity of gold and amalgam fillings. Under the circumstances, the fillings act as the poles of a battery and in the presence of saliva, which supposedly acting as an electrolytic fluid, generates a weak electric current. This current is transmitted to the pulp with resultant irritation and occasional hyperemia.

Similar electric irritations were formerly produced in the use of the cataphoric current for "cataphoresis" operations about the teeth for relief of hypersensitive dentin and often resulted in hyperemia, inflammation and ultimate death of the pulp. The careless use of electric machines for testing the vitality of the pulp may also produce similar reactions and pathologic disturbances. Fig. 851.

Extension of Vascular Disturbance from Other Parts.—Pulp irritations occasionally result from extension of a hyperemic or an inflammatory area in the pericementum of the affected or adjacent teeth. Alveolar abscess or a pyorrhea pocket on an adjoining tooth may also, through the circulatory apparatus, produce pulp disturbance. Similar conditions may occasionally arise from an inflamed or infected tooth socket following extraction operations. Most of these cases are due to true circulatory disturbances and an extension of the inflamed area from one part to another, as a result of the close anastomotic vascular connections. In other cases, it is claimed that reflex nervous action may be concerned. Cases have been reported of pulp hyperemia or inflammation being produced from the presence of a similar condition in the pulp of an adjoining tooth, the resultant condition being attributed to a true nervous reflex. Any inflammation along any branch of the fifth or trigeminal nerve may cause reflex disturbances in other parts supplied by that nerve, or through close anatomic relationship the disorder may manifest itself in parts sup-

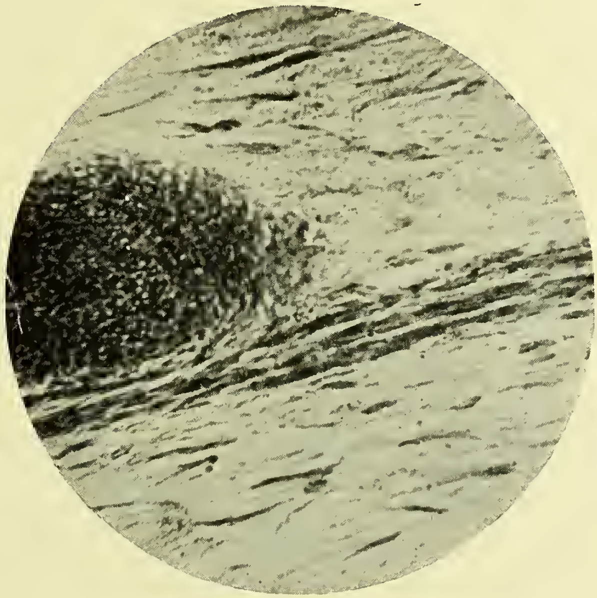


FIG. 851.—Axis cylinders of nerves in the pulp. (Courtesy of Dr. Harold K. Box.)

plied by adjacent nerves. These phenomena have been discussed in the chapters on "Diagnosis" to which the student is referred.

SYSTEMIC CAUSES

The pulp is an end circulatory organ and is readily affected by constitutional disturbances involving the terminal vessels. Such systemic conditions as common cold, grip, malaria, menstruation, syphilis, mercurial and other systemic poisons may manifest themselves in the oral cavity with the production of pericemental and subsequent pulp irritations, inflammations and other disturbances. Anemia, febrile disease and general systemic debility may lower the vital activity and resistive powers of the pulp and render it more subject to injury.

CHARACTER OF RESPONSE TO INJURY

The type of reaction of the pulp to injury will depend largely on (1) the nature and extent of the various local and systemic causes of pulp disturbance mentioned and (2) on the vital resistance of the pulp to attacking agencies, as regulated by the general health and cell resistance of the patient. As previously emphasized, the reaction to stimulants and irritants may manifest itself in the form of the various acute diseases, such as arterial and venous hyperemia, inflammation, suppuration and gangrene. In other instances, protective reactions may arise in the nature of tubular calcifications, secondary dentin or pulp nodule formations, while otherwise, some of the forms of chronic low grade inflammations and degenerations may manifest themselves. Mild, low grade, long continued causes and forms of irritations usually produce the constructive calcareous types of pulp disturbance or the chronic inflammatory and degenerative manifestations; while the acute diseases are usually the result of more marked, highly developed and rapidly acting types of causes. Much will depend, however, on the state of health and natural cell resistance of the patient. There is frequently no definite line of demarkation between the various types of pathology manifested. A pulp may early begin to form constructive, protective substances and later succumb to degenerative changes. In fact, degeneration and death of the pulp is the usual outcome of all untreated pathologic disturbances of the organ. In the chronic forms, the disease may be extended over many months or years, while in the acute types the condition may run a riotous course and result in early death of the pulp in a few days or weeks. In the later stages of the chronic varieties, infection and acute symptoms may manifest themselves, with resultant quick death of the pulp. In other cases with high resistive powers, the case may run a slow, uneventful course, extending over long periods of time, causing very little if any disturbance and occasionally being accidentally discovered.

SYMPTOMS AND DIAGNOSIS OF PULP DISTURBANCES

Vascular and Nerve Reactions.—The clinical manifestations of pulp disturbance are largely due to pathologic changes taking place in the vessels and vasomotor and sensory nerves of the part. As a result of the action of the irritants previously mentioned, the vaso-motor nerves supplying the vessel walls are first stimulated, then over-stimulated, and finally paralyzed. The same conditions occur in the sensory nerves, with the result that in the early stages of pulp disturbance, arterial and venous hyperemia (congestion) occur from loss of tone in the vaso-motor nerves supplying the vessel walls. The resultant dilatation of these walls produces lateral pressure on the sensory nerves immediately adjacent, with the production of pain. As the condition increases in degree, stagnation of the blood currents results from pressure on the afferent and efferent blood currents passing through the apical foramen (jugulation). At the same time, progressive, degenerative changes are occurring in the nerves of the part, with increased tendency to dilatation, loss of tone and rupture of the vessels, following which, the condition of inflammation is fully established. This condition, long continued, finally produces complete paralysis of both sensory and vaso-motor nerves, with ultimate death and loss of sensation of the pulp, from loss of the functional activities of its vascular and nerve supply. Figs. 852 and 853.

Pain.—If germs enter and suppurative or putrefactive changes occur, the pressure of the gases being formed in conditions of this nature is also productive of pain, so long as any vitality remains in the sensory nerves of the pulp. It may thus be seen that the *pressure element* is largely concerned in the production of the painful sensations manifested in diseases of the organ. The terminal nerves of the pulp are not supplied with tactile endings, hence the organ has no sense of location. One of the chief characteristics of pulp disturbance is *pain of a reflex nature*—indefinitely located pain referred to an adjoining tooth or to distant parts. The character and extent of the pain exhibited greatly assists in making a diagnosis of the pathologic disturbances present.

Thermal Tests.—Pulps are peculiarly susceptible to changes of temperature, since, as is well known, the application of cold produces contraction, while heat causes expansion of tissues richly endowed with a blood supply. The temperature tests (thermal tests) of G. V. Black

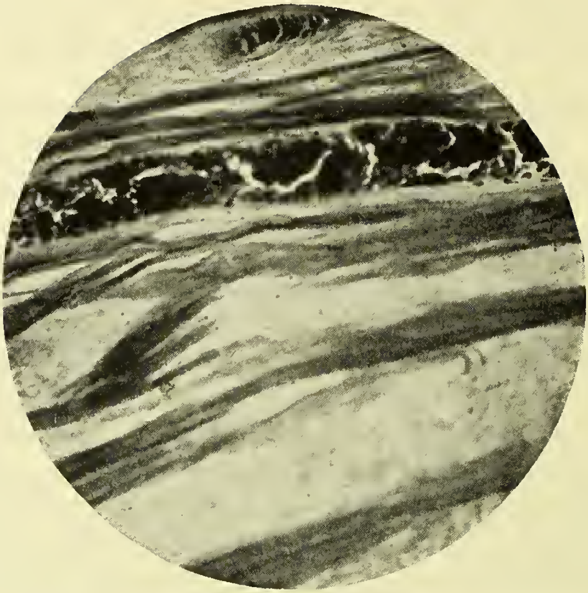


FIG. 852.—Medullary sheath of pulpal nerves. (Courtesy of Dr. Harold K. Box.)

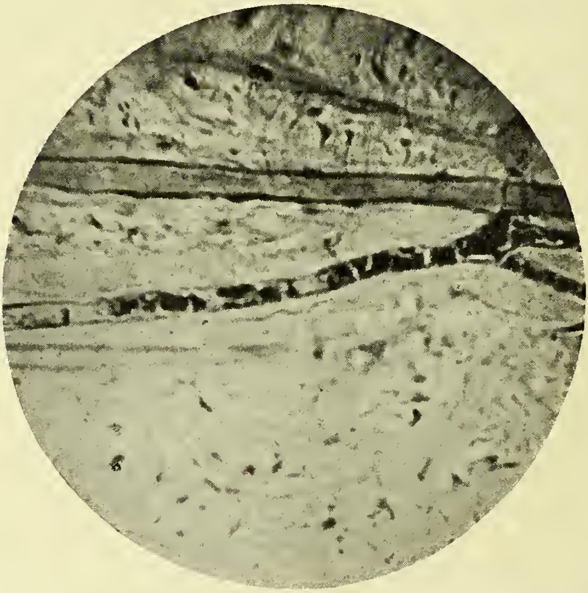


FIG. 853.—Capillaries on the periphery of the pulp. (Courtesy of Dr. Harold K. Box.)

and Louis Jack, devised years ago, are still of great value in making a diagnosis of pulp disturbance. The reactions to these tests may be outlined as follows, although the exact relationships between the pathologic changes taking place and the response elicited never have been thoroughly worked out:

First.—Most teeth are normally accustomed to changes of temperature, ranging between sixty degrees and one hundred and five to one hundred and ten degrees Fahrenheit, and within this range, if the pulp be in a healthy condition, do not usually respond to these applications. However, there may be great variation in the response of different individuals to thermal tests. Consequently, in applying them an attempt should at once be made to determine the normal response or irritation point for each patient.

Second.—If a jet of water at a temperature of forty degrees Fahrenheit be applied to a healthy tooth, the act is followed by a quick sharp contraction pain which immediately disappears on withdrawal of the irritant. Hot water will produce a similar response, viz., the normal pulp responds indifferently to either heat or cold.

Third.—With the progressive loss of enamel and dentin, through caries and other conditions, the reaction to thermal stimuli gradually increases in promptness until, when the pulp is nearly exposed, the response is immediate.

Fourth.—As irritation of the pulp increases in amount from the constant action of external agencies, there gradually arises prompt response to lesser and lesser degrees of temperature change, until the pulp finally responds to temperatures near 98.6°F., viz., body temperature.

Fifth.—The character of the pain elicited also changes from a sharp contraction pain, disappearing readily in the early stages of pulp disturbance, to a heavy, throbbing, continuous pain, as the condition progresses. Still later, the pain will frequently manifest itself without apparent source of irritation, or on assuming the recumbent posture.

Sixth.—In suppurative conditons of the pulp, intense pain frequently is manifested from applications of heat, while cold often relieves. Passage from a cold to a warm atmosphere or contact with hot foods frequently produces paroxysms of pain.

Seventh.—Still later, after paralysis of the sensory nerves of the pulp has occurred and death of the organ has taken place, no response is elicited, even by prolonged application of a spray of ethyl chlorid, although prolonged application of heat may cause a response, from expansion of the gases of putrefactive decomposition and resultant pressure on the periapical tissues.

Eighth.—In the constructive diseases of the pulp, viz., tubular calcification, secondary dentin, pulp nodules and calcareous degeneration, as well as in the other chronic degenerations, response to applications of heat and cold is usually increasingly delayed with the progress of the disturbance, with the result that in the later stages of cases of this nature it is frequently only after prolonged application of intense heat or cold that a response is obtained.

TESTS FOR PULP VITALITY

None of the tests for vitality of the pulp are absolutely infallible. The only sure test is entrance into the pulp chamber and direct contact with the contents of the chamber and canals. However, the procedures herewith given will be of assistance in making a diagnosis.

First.—Transillumination of the tooth by means of an electric mouth lamp. A vital tooth will appear translucent and pink, while a non-vital one will be opaque and often clouded to a gray or bluish black color. Discoloration and darkening of the tooth are characteristic of non-vital teeth, although in many instances these phenomena are absent.

Second.—Prolonged application of iced water, a small spicule of ice, or a spray of ethyl chlorid will elicit no response from a non-vital tooth.

Third.—Application of a hot burnisher, hot guttapercha or hot water to a non-vital pulp will be negative as far as pain production is concerned, unless in closed cases from expansion of the gases of putrefaction and consequent pressure on the periapical tissues.

Fourth.—Application of the mild electric current will produce a response from a vital pulp, while none will be obtained in a non-vital case.

Electrical Tests.—Numerous types of electric pulp-testing apparatus may now be obtained for this purpose. In using some of them one electrode is placed in contact with the suspected tooth, while the other is held by the patient, or is placed in contact with the wrist or some other part of the body. In the more modern forms both electrodes are brought directly in contact with the tooth. The current is now turned on and gradually increased in amount. A dead tooth will not respond to the strongest current of which the machine is capable, while a vital tooth will respond with varying degrees of intensity, depending on the susceptibility of the individual and the state of health of the pulp tested, the teeth of some patients responding more readily than others, and diseased vital pulps responding more or less readily, depending on the pathologic condition present.

In testing vital pulps for the presence or absence of pathologic disturbances, the following procedures may be followed: Apply the current to several known vital teeth, until a tingling sensation is felt, but not until pain is produced. The average current necessary to produce this sensation is termed the irritation point. After having established on the machine the irritation point for the patient, it is now a simple matter to distinguish diseased from normal pulp reactions. The following reactions will be of value in determining the probable condition present:

1. A normal pulp will respond to the current at the irritation point.
2. An irritated pulp will respond at or just below the irritation point.
3. An inflamed pulp will respond below the irritation point, the greater the degree of inflammation present, the more ready the response.
4. A suppurative pulp will respond above the irritation point, the more severe the suppurative condition, the less ready the response.
5. A devital pulp will give no response whatever to the full strength of the current.

ARTERIAL HYPEREMIA (ACTIVE CONGESTION)

This condition is essentially an excess of blood in the dilated arteries and capillaries of the pulp. In mild, long continued cases, the cells of the pulp may be stimulated to increased activity, with resultant production of tubular calcification, secondary dentin or pulp nodules. In the graver cases, with highly active exciting causes, venous hyperemia usually supervenes. Figs. 854, 855 and 856.

It has been stated several times in this work that pulps which have not passed beyond the stage of arterial hyperemia frequently may be restored to health and even in cases of exposure may occasionally be subjected to the pulp-capping operation. For diagnostic purposes the symptoms of arterial hyperemia may here be mentioned as follows:

Symptoms and Diagnosis.—*Pain.*—Intermittent, not continuous pain, of recent origin, or a lancinating character, indefinitely located, is characteristic. The pain may arise in the absence of tangible external sources of irritation, and, being of a reflex nature, may be referred to an adjoining tooth, to the gum, to the eye, to the ear and other distant parts.

Thermal Reaction.—Application of mild degrees of cold or heat usually produces a quick, sharp contraction pain, passing away immediately and not reappearing. A blast of cool air from the chip blower,

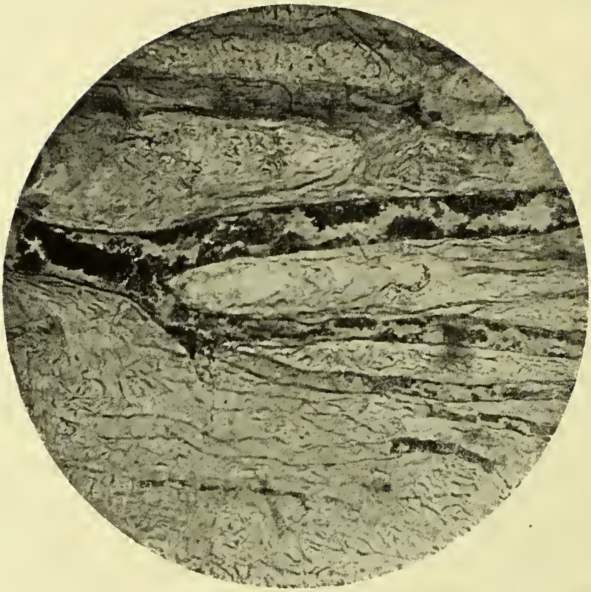


FIG. 854.—Pulpal artery and its branches. (Courtesy of Dr. Harold K. Box.)

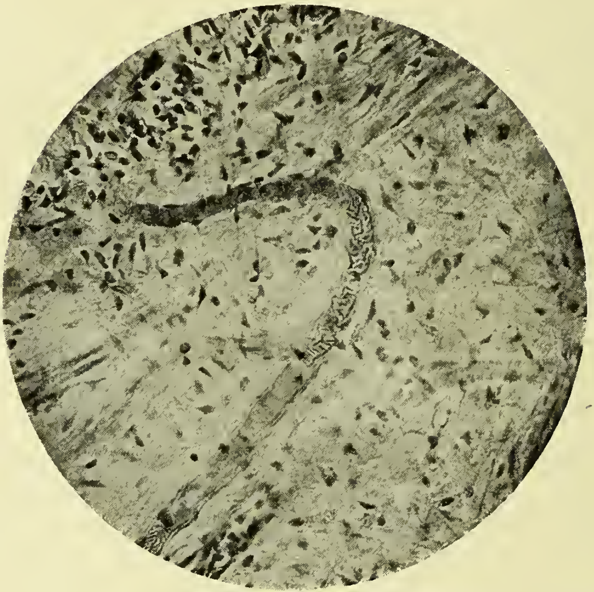


FIG. 855.—Capillary hyperemia of the pulp. (Courtesy of Dr. Harold K. Box.)

or a drop or two of water at 60°F. usually is sufficient to produce the above characteristic response. The tooth should usually be isolated with the rubber dam.

Electric Test.—The application of the electric test usually produces a response slightly below the irritation point.

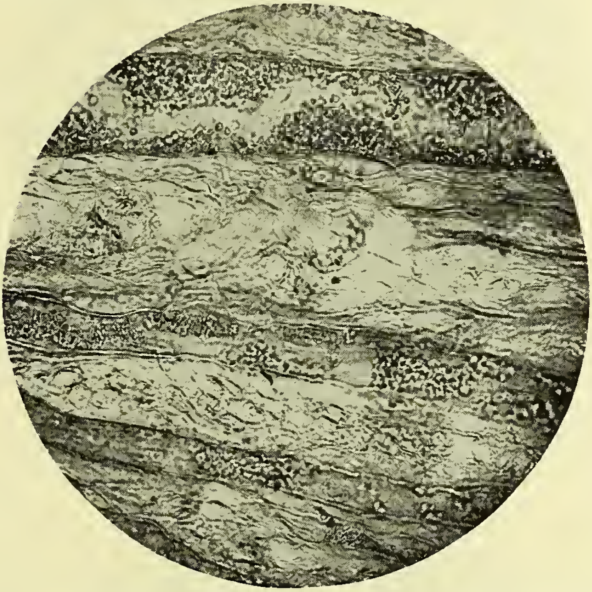


FIG. 856.—Arterial hyperemia of the pulp. (Courtesy of Dr. Harold K. Box.)

Other Symptoms.—The history, presence or absence of decay, pulp exposure and other objective symptoms, as well as the nature of the cause will greatly assist in the diagnosis.

VENOUS HYPEREMIA (PASSIVE CONGESTION)

The cause concerned in the production of venous hyperemia is the presence of arterial hyperemia resulting from any of the non-infective conditions previously mentioned as causes of pulp disease. As a result, return of blood from the pulp via the veins is interfered with and partial stasis is produced. Often thrombosis of vessels in the apical foramina occurs. A blow on a tooth is also likely to produce tearing and jugulation of the vessels at the apex, with resultant thrombosis and stasis. As a result of internal pressure of blood within the vessel walls and loss of tone and nerve control, dilatation and rupture occurs, with passage of lymph and diapedesis of red blood cells into the interstices of the pulp. The hemorrhagic extravasations (hemorrhagic infarcts) continuing, cause compression of the cellular elements of the pulp and

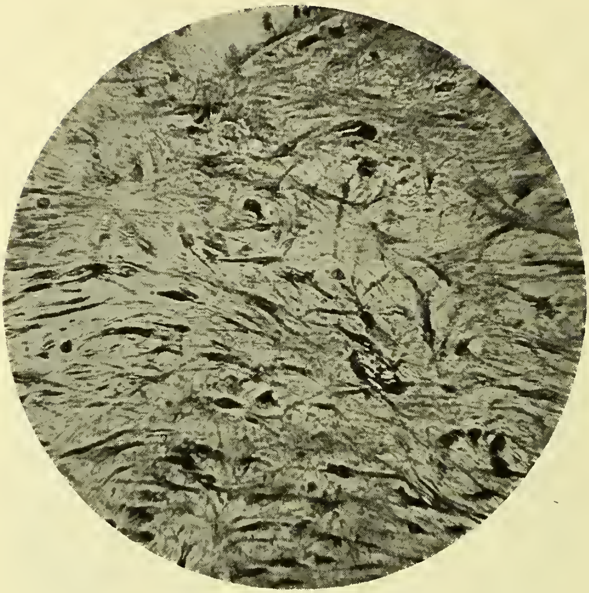


FIG. 857.—Pulp cells in a normal pulp. (Courtesy of Dr. Harold K. Box.)

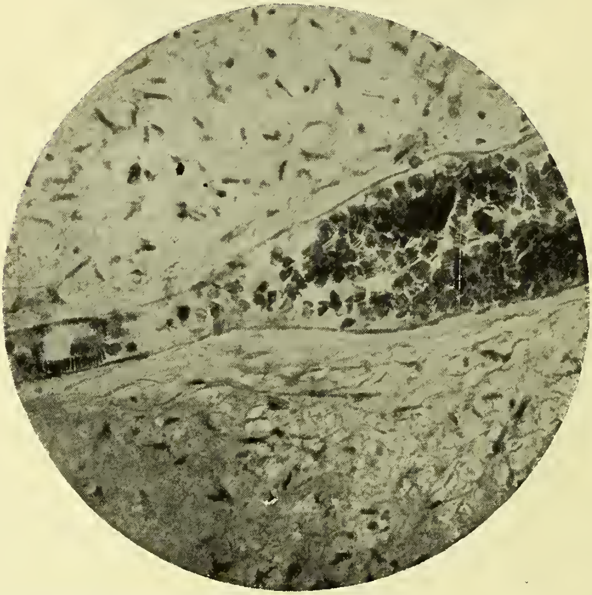


FIG. 858.—Pathological hyperemia of the pulp. Red blood cells grouped in rouleaux. (Courtesy of Dr. Harold K. Box.)

disintegration of the red corpuscles. Following this, hemoglobin is sometimes diffused into the dental tubules and color changes may be manifested in the tooth. This condition is known as "suffusion" and the tooth may first appear pink in color, rapidly passing to purple, dark blue, black, yellow or brownish tints. In many cases, suffusion does not occur. In cases of partial jugulation, the bulbous portion of the pulp may die, while the radicular portion may remain alive. In other cases, the entire pulp may continue in a low state of venous hyperemia for long periods of time, depending on the nature of the cause and extent of the injury. Figs. 857 and 858.

Symptoms.—The principal symptoms are a feeling of fullness in the tooth or paroxysms of continuous pain, lack of response to the application of sedatives for relief, increased response to thermal and electric tests and sometimes change of color. If bleeding occurs as a result of accidental pressure on the exposed pulp, or of premeditated puncture with an instrument, or application of warm water, pressure, fullness and pain are often relieved. In view of the pathology, it may readily be understood that restoration of the pulp to normal conditions occurs very rarely and usually only in the early stages and in very mild cases.

PULPITIS (INFLAMMATION)

The essential pathologic features of inflammation of the pulp are those incident to arterial and venous hyperemia previously described, together with further enlargement, dilatation and rupture of the walls of the veins and arteries with resultant passage, emigration and disintegration of the leucocytes into the interstices of the pulp. Pulpitis may be *infective* or *non-infective* in character. The simple, non-infective types may often be of the chronic variety. The non-infective forms, however, frequently become infective from the later entrance of germs. Or aerobic germs may be present and produce no harm until air is admitted through an open cavity, when they may suddenly spring into activity under the influence of the changed environment and the admission of sufficient oxygen for their multiplication, propagation and activation. Pulpitis may be *partial* or *complete*, occupying one horn or other localized area, or involving the entire substance of the pulp. Also, it may be *acute* or *chronic*, *purulent* or *non-purulent*, depending on the extent and activity of the cause, the cell resistance of the parts and the presence of suppurative micro-organisms. The acute form is more frequently infective, partial and purulent, although opposite types are often seen. The chronic variety is more often non-infective, extensive or complete, non-purulent and followed by secondary degenerative changes, such as secondary dentin and pulp nodules, or by fibroid, calcareous and other forms of degeneration. Fig. 859.

Acute Pulpitis.—This is an active violent inflammation of the pulp following venous hyperemia, produced usually by the more pronounced and severe causes previously outlined, or resulting from the action of milder causes on tissues with low resistive powers. In very rare cases, resolution and recovery occurs through the usual processes of repair. In many instances, the condition runs a violent, rapid course, terminating in stasis and coagulation necrosis. In others, infection with suppurative bacteria results in the early production of suppurative pulpitis. Occasionally in the absence of suppurative bacteria, the acute symptoms may subside and the disease continue over a considerable period of time as a chronic pulpitis followed by some of the constructive or destructive degenerative disturbances. In all instances, where resolution does not occur, the ultimate termination is death of the pulp. Fig. 860.

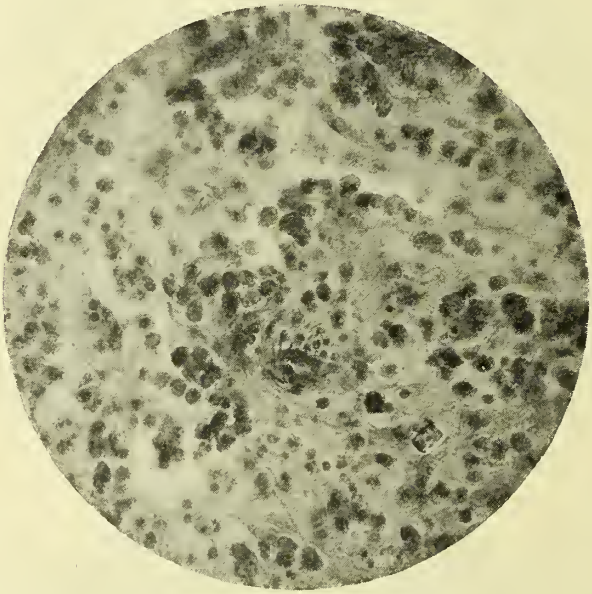


Fig. 859.—Diffuse infiltration of the dental pulp. (Courtesy of Dr. Harold K. Box.)

Symptoms and Diagnosis.—In the early stages, the pain may be indefinitely located or reflex in character. As the condition progresses, the character of the pain quickly changes to a heavy, boring, intermittent, throbbing pain, usually worse on assuming the recumbent posture and

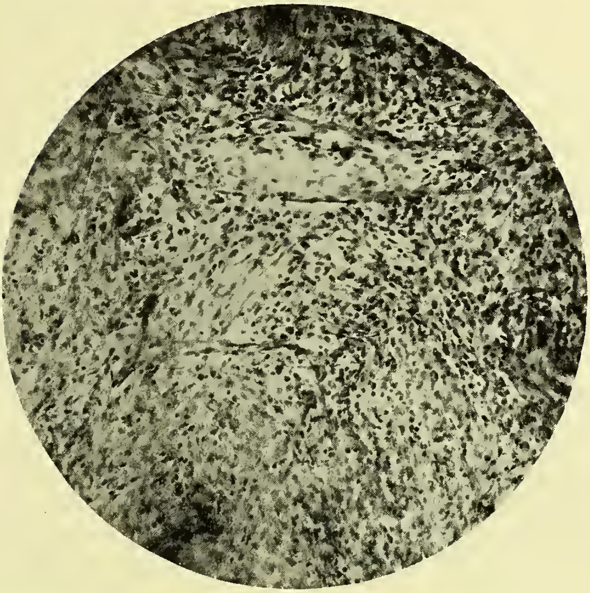


FIG. 860.—Diffuse plasma cell infiltration of the pulp. (Courtesy of Dr. Harold K. Box.)

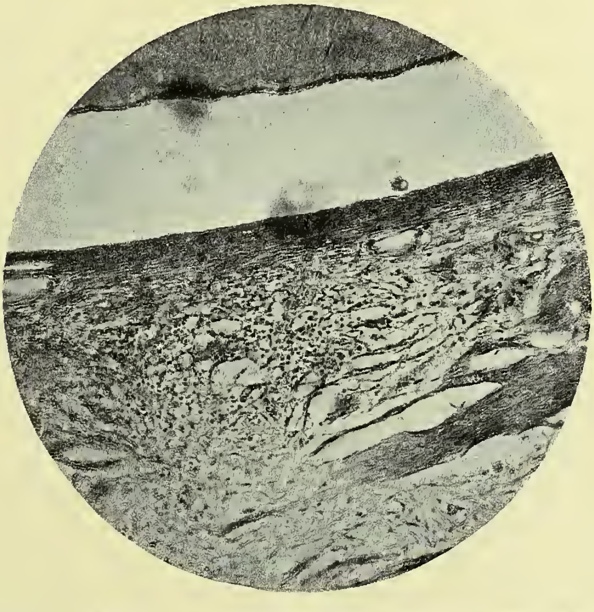


FIG. 861.—Ulceration of the pulp. Small leucocytic infiltration near the surface (Courtesy of Dr. Harold K. Box.)

at night. In fully developed, active cases, the pain often becomes more definitely localized in the affected tooth and tends to become more continuous in character, although it may be accompanied by reflex pains and neuralgia in other parts of the face, head or distant localities. The pulp responds to applications of mild degrees of both heat and cold in the form of a paroxysm of pain of a continuous nature. Contact of hot and cold foods, sweet and acid substances or the packing of food into an open cavity may produce a sudden paroxysm of pain which does not readily subside. In the later stages of acute pulpitis, tenderness of the tooth to tapping or pressure may arise, from passage of the inflammatory area to the tissues of the apical space. Diagnosis is made through recognition of the above symptoms, response to thermal and electric tests, history of the case, study of the possible causes, and observation of the objective signs present. The presence of a large open cavity of decay, a large filling, a leaky filling, an exposed pulp, or a history of trauma or similar conditions should assist in completing the diagnosis.

Suppurative Pulpitis (Suppuration of the Pulp).—This is a frequent sequal to acute pulpitis. The presence of, or later entrance of suppurative germs through the aforementioned avenues, with or without pulp exposure, inaugurates suppurative processes, either on the surface or in the interior of the inflamed pulp. The disease may manifest itself in the form of ulceration or abscess of the pulp. *Ulceration,* located on the surface is the more common form. Figs. 861 to 864. The pus-forming bacteria liquefy the pulp tissues and transform them into pus, gradually eating their way deeper and deeper, hollowing out the organ and finally breaking it down and destroying it. The necrotic portion finally undergoes putrefactive decomposition. The condition in the early stages may be confined to a local area, such as a pulp horn, the rest of the pulp being acutely inflamed, but, if untreated, gradually extends through a period of weeks or months, until the entire pulp is involved and destroyed. In *abscess* of the pulp, the peripheral tissues of the pulp are still intact and unbroken, the interior of the pulp being gradually hollowed out, broken down, transformed into pus and destroyed by the suppurative micro-organisms. By extension and enlargement, the abscess may finally break through to the surface. The surrounding areas are acutely inflamed. Figs. 865, 866 and 867.

Symptoms.—The predominant symptoms are the presence of the characteristic odor of suppuration and putrefaction, and a dull, gnawing pain, frequently of a continuous character. The patient may be fairly comfortable during the periods of quiescence. Pain is usually produced

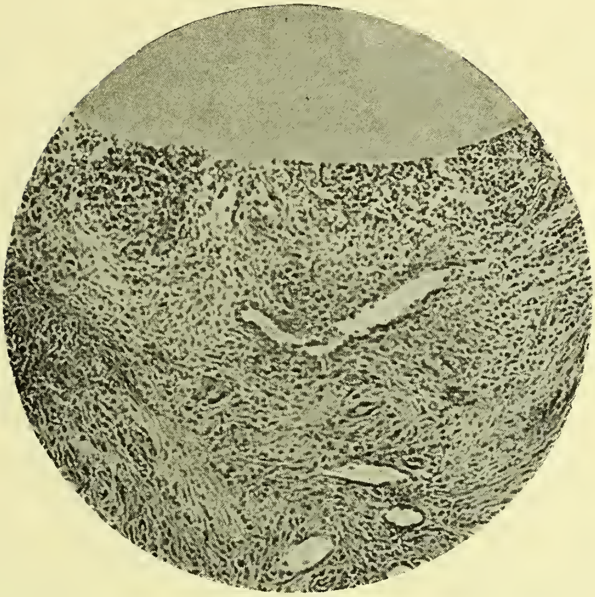


FIG. 862.—Ulceration of the pulp, later stage than that shown in Fig. 861. (Courtesy of Dr. Harold K. Box.)

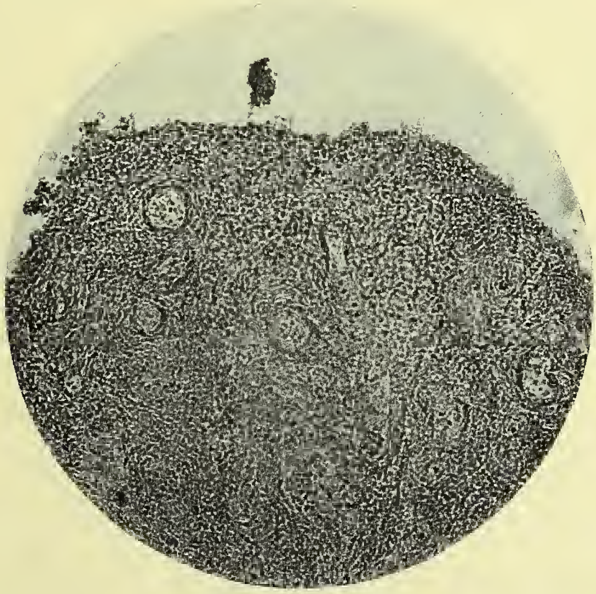


FIG. 863.—Ulceration of the pulp, still later stage. (Courtesy of Dr. Harold K. Box.)

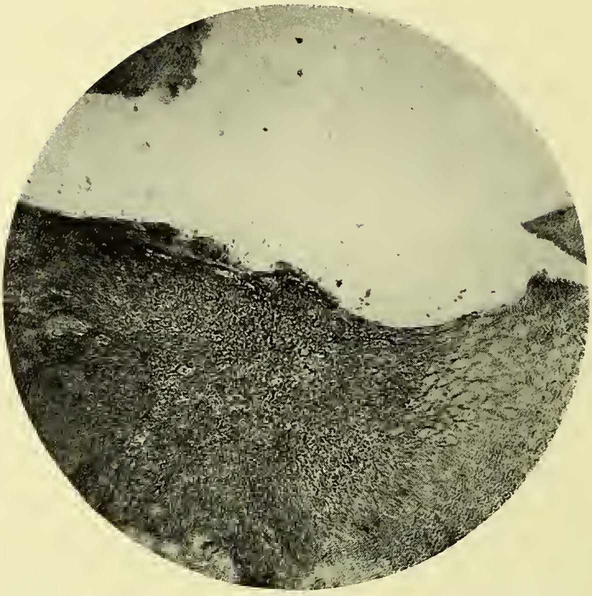


FIG. 864.—Ulceration of the pulp. (Courtesy of Dr. Harold K. Box.)

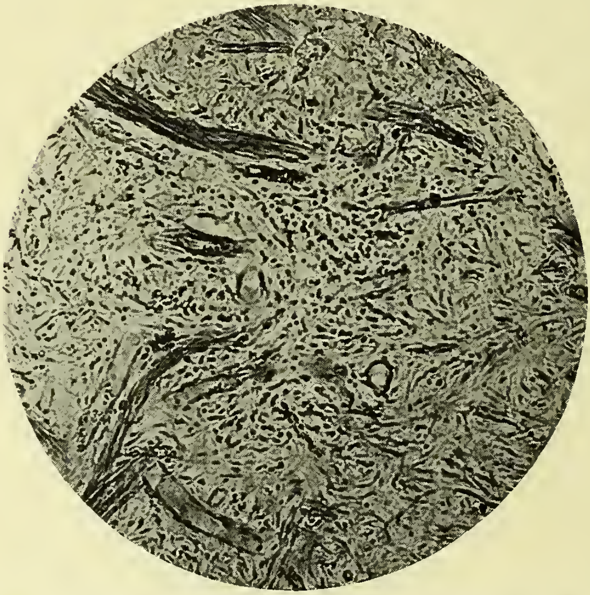


FIG. 865 —Abscess of the pulp. Small leucocytic infiltration in the deep tissues of the pulp. (Courtesy of Dr. Harold K. Box.)

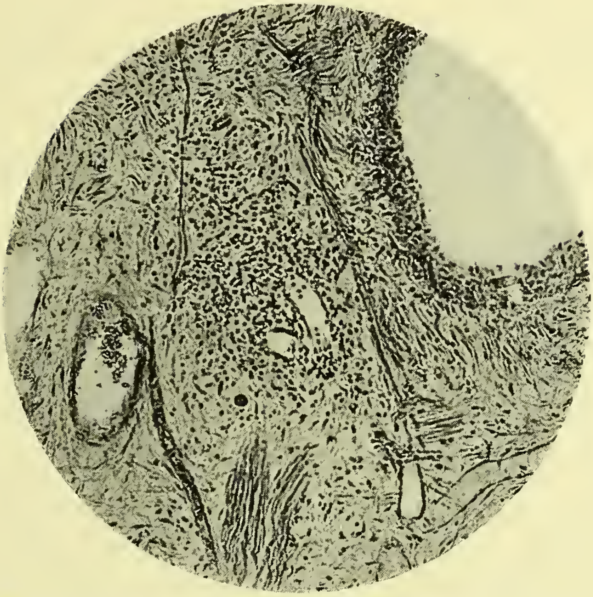


FIG. 866 —Abscess of the pulp. Later stage than that shown in Fig. 865. (Courtesy of Dr. Harold K. Box.)

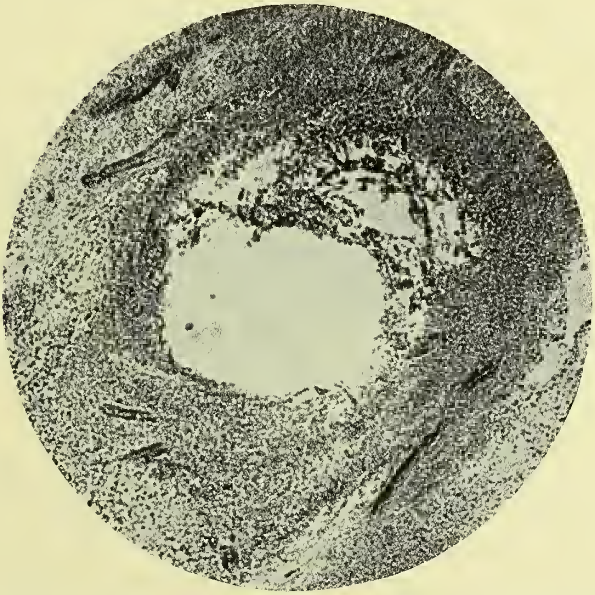


FIG. 867.—Abscess of the pulp. (Courtesy of Dr. Harold K. Box.)

and increased in amount by heat and relieved by cold applications. Taking into the mouth of hot foods or drinks, or passage from a cold exterior to a warm room may start a paroxysm of pain. Pus may be present on the surface in ulceration and may exude with blood into the cavity through an open exposure. In abscess the presence of pus may not be apparent unless the pulp is punctured, when, in the latter instance, pain may subside from bleeding, pus flow and relief of the internal pressure. Tenderness of the tooth to percussion or pressure may appear in the later stages, from involvement of the pericementum. Reflex pains in adjacent and distant parts may manifest themselves.

Chronic Pulpitis.—In the presence of the milder types of causes and a high degree of pulp vitality and resistive power, low grade, long continued chronic inflammations of the pulp may occur. Also, acute inflammatory changes, which do not immediately terminate in death of the tissue may resolve themselves into the chronic types. In either case, malnutrition, asphyxiation and various retrogressive changes may occur. These may consist of the various forms of degeneration previously mentioned, such as fibroid, fatty, mucous or hyaline degeneration, or calcareous formations may occur in the tissues. Fibroid and other types of degeneration often occur with advanced age without apparent or marked clinical symptoms of inflammation. The fibroid and other types of degeneration occurring as a result of chronic inflammation or as natural old age terminations are due to irritation, a lowered blood supply, asphyxiation and lack of nutrition in the affected pulp. The microscopic appearance is similar to that as found in the same conditions in other tissues, modified by the histologic characteristics of the pulp tissue in which they are found. Figs. 868 to 871.

Symptoms.—All chronic inflammations and degenerations of the pulp may show long continued discomfort, with no great amount of pain and a lowered or slow response to thermal and electric tests. The response to both heat and cold usually declines and in the later stages may be very slow or nearly absent.

Chronic Hypertrophic Pulpitis (Hyperplastic Pulpitis).—This condition, of relatively rare occurrence, consists of a hypertrophy of pulp tissue, protruding through an exposure into a large, widely open cavity. It is the result of chronic inflammation, with swelling and protrusion of the enlarged mass through the point of exposure. The rough, jagged edges of the exposure and of the cavity frequently stimulate and hasten the hypertrophic growth. In cases of wide, open exposures the mass in the pulp chamber and that in the carious cavity may be continuous.

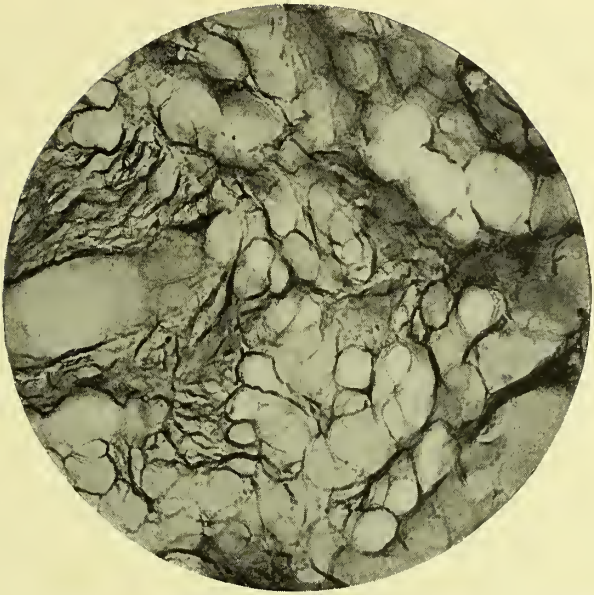


FIG. 868.—Areolation or oedema of the pulp. (Courtesy of Dr. Harold K. Box.)

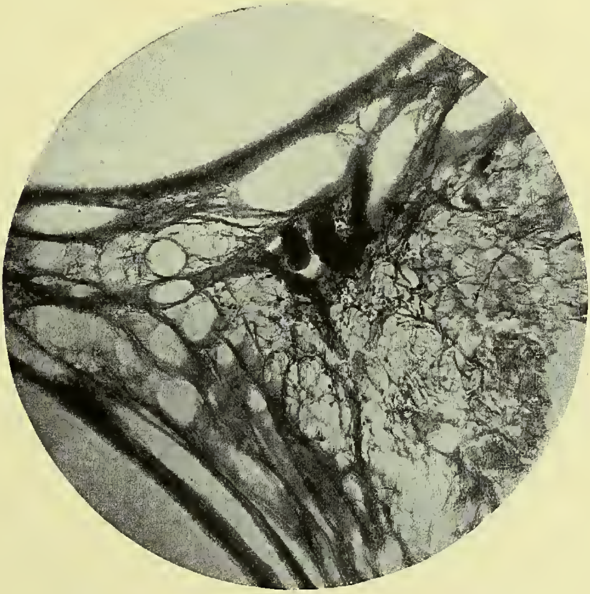


FIG. 869.—Fibroid degeneration of the pulp. (Courtesy of Dr. Harold K. Box.)

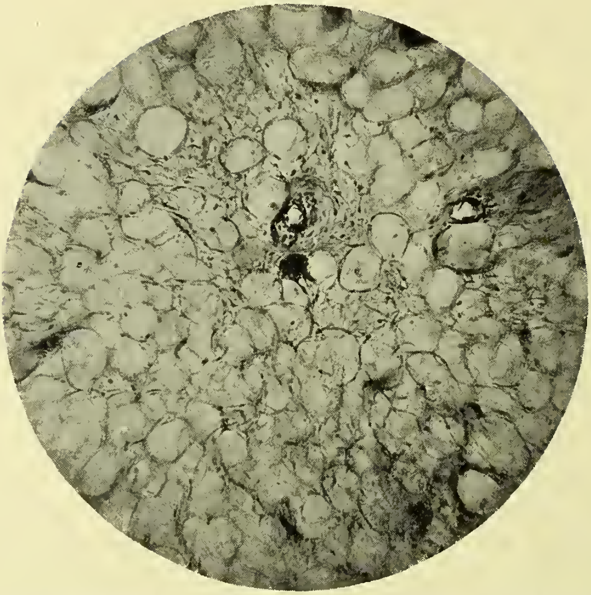


FIG. 870.—Fatty degeneration of the pulp. (Courtesy of Dr. Harold K. Box.)

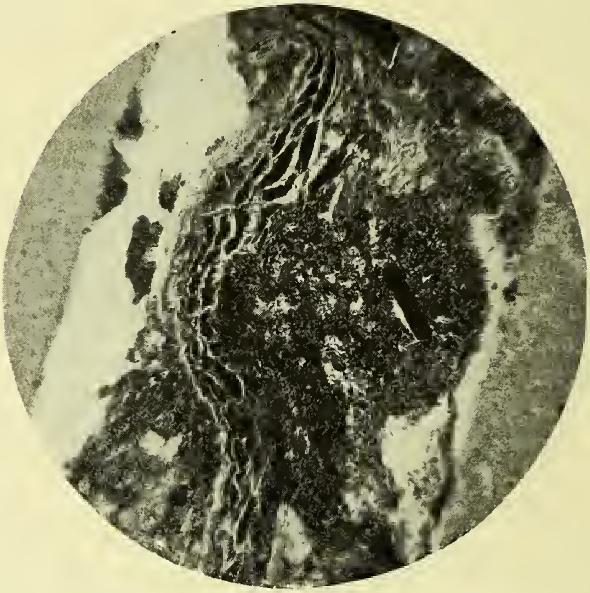


FIG. 871.—Hyaline degeneration of the pulp. Hyaline in the connective tissue cells. (Courtesy of Dr. Harold K. Box.)

With small exposures, that part of the growth occupying the cavity may be attached by a small pediculated base to the chronically inflamed pulp in the pulp chamber and present in the form of a polypus. The overgrowth develops blood vessels, but a very low nerve supply, consequently it may bleed profusely on puncture or touch, but is largely insensitive unless pressure is transmitted to the underlying pulp in the chamber.

The hypertrophic mass may occasionally be mistaken for hypertrophied gum tissue growing into the cavity through a lateral opening at the neck of the crown or junction of the roots. The pulp tissue is usually more sensitive and bleeds more readily. Hypertrophied gum tissue is usually tougher and more fibrous. A history of the case frequently will assist in the diagnosis, hypertrophic pulp often giving a history of previous pain and other symptoms of pulp disturbance. The use of a flat-bladed instrument will sometimes enable the operator to expose the attachment of the mass to the gum at the gingival margin, in case it is gum tissue. Sometimes the ablation of the bulk of the mass is necessary before a correct diagnosis can be made, especially in cases of perforation of the pulp chamber and growth of the mass through the opening into a large cavity in a badly broken-down tooth. Resorption of the walls of the pulp chamber, with consequent enlargement of its diameter is an occasional accompaniment of hyperplastic pulpitis. The bulk of the mass is composed of granulation tissue with a stroma of fibrous connective tissue, covered by a layer of stratified squamous epithelium.

PULP NODULES (PULP STONES; NODULAR CALCIFICATION)

As a result of long continued irritation, congestion or inflammation, calcification may occur within the tissues of the pulp. Pulp stones or nodules are hard, translucent or semi-translucent, calco-globulinous bodies occasionally found in the interstices of the pulp. They are often associated with abrasion, erosion, slowly progressing caries or similar causes concerned in the production of chronic affections of the pulp. Hopewell-Smith in his Normal and Pathological Histology of the Mouth, Vol. II, page 20 considers them to be a secretion of the pulp cells as a result of irritation in the presence of hyperemia and chronic inflammation. Many theories have been advanced as to the probable mode of formation by Adami, Mallory, Black, Burchard, Box and others. They may be small or large, multiple or single, of various shapes and located in the bulbous or radicular portion of the pulp. They are more often seen in middle aged patients. When first secreted, they consist of soft calco-globulinous material, which later hardens. The deposition of additional

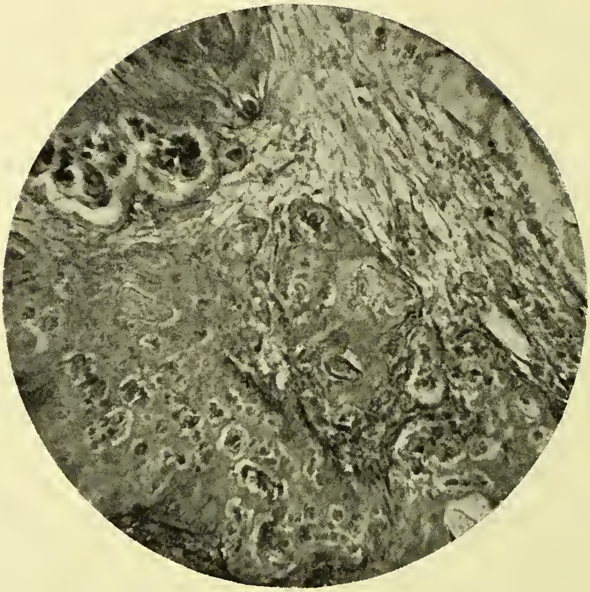


FIG. 872.—Calcoglobulin deposit in the pulp. (Courtesy of Dr. Harold K. Box.)

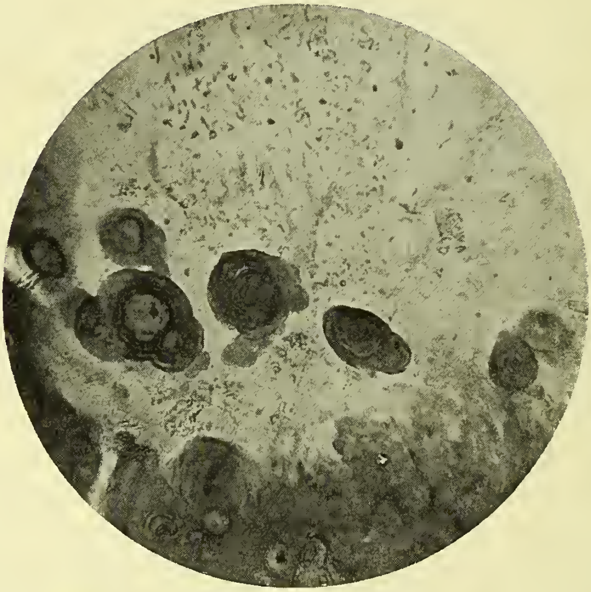


FIG. 873.—Calcospherites in the dental pulp. (Courtesy of Dr. Harold K. Box.)

layers produces a concentrically laminated mass of calco-spherites, sections of which give, under the microscope in their typical form, the appearance of a split onion. Several small nodules may unite to form a single larger one, which will present, microscopically, several circularly laminated masses surrounded by structureless material. One or several teeth may be affected. In the latter instance, the probable cause may be a general form of irritation affecting several pulps, or reflex irritation may be concerned. Figs. 872, 873 and 874.

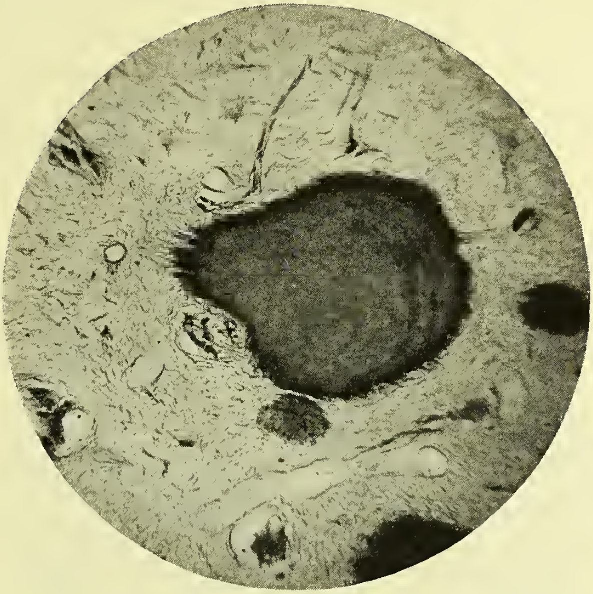


FIG. 874.—Serrated pulp nodule. (Courtesy of Dr. Harold K. Box.)

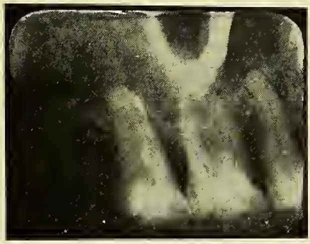


FIG. 875.—Pulp stones, first and second molars. Alveolar absorption, second bicuspid.

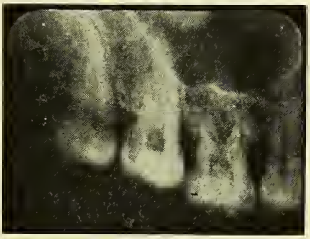


FIG. 876.—Pulp nodules. Absorption of roots of first molar.

Symptoms.—The symptoms are frequently vague in character. Those of large size may be accidentally discovered in making routine roentgenographic diagnosis. Pain or discomfort may be absent or the affected pulps may exhibit increase in thermal and electric reactions. Reflex pains are often present with both small and large deposits. Persistent neuralgias of the eye, ear, scalp, and tenderness on pressure at the infra-orbital foramen are frequently discovered on closer examination. With small deposits, there may occasionally be no subjective symptoms, or there may be extreme response to cool water. With large deposits, the dentin may be almost devoid of sensation, or may respond very slowly to thermal tests, indicating marked retrogressive and degenerative pulp changes. Pulp stones may occasionally be of such size as to almost occlude the entrance to the pulp chamber or canals. Ordinarily they have no connection with the walls of the pulp chamber or canal. Occasionally they are found concomitantly with secondary dentin formations, and under these circumstances may become united with them in case of extensive growths of both types of constructive reaction. Figs. 875, 876 and 877.

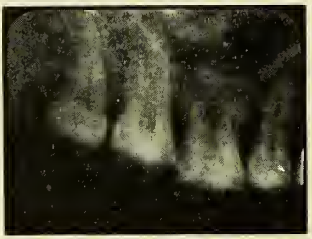


FIG. 877.—Pulp nodules. Root resorption on second bicuspid and first molar.

CALCAREOUS DEGENERATION

Calcareous masses may be found in chronically congested and inflammed pulps as a result of depositions, rather than of secretion. Calcareous deposits of this nature are different in structure, form, consistence and appearance from pulp nodules. During pathologic conditions, certain substances may attract lime salts. Necrotic and diseased tissue anywhere may become calcified. Calcareous degeneration of the pulp is attributed to the presence of a semi-stagnant blood stream in cases of exhaustion and degeneration of pulp tissue from chronic hyperemia and inflammation of long standing. Many theories have been advanced by different authorities to account for these depositions. According to Burchard—Inglis in Dental Pathology and Therapeutics, sixth edition, page 377, they are due to an acidosis, with excess of carbon dioxide and catabolic products which favor deposition of calcium salts.

The masses may be either tubular or cylindrical in form and are deposited about or along the increased fibrous elements of the pulp.

They are usually soft, brittle, opaque and of small size—sometimes microscopic, occasionally larger. Pulps affected with the condition usually are easily removed *en masse*, present a granular feel to the fingers and when dry, become hard and thorn-like. Fig. 878.

The symptoms are usually vague, though following the usual manifestations of chronic inflammation and degeneration of the pulp. Reflex pains and neuralgia are often present. The pulp often responds more to heat than to cold, but the response to both heat and cold is generally delayed. Large deposits will occasionally be revealed in the roentgenogram.

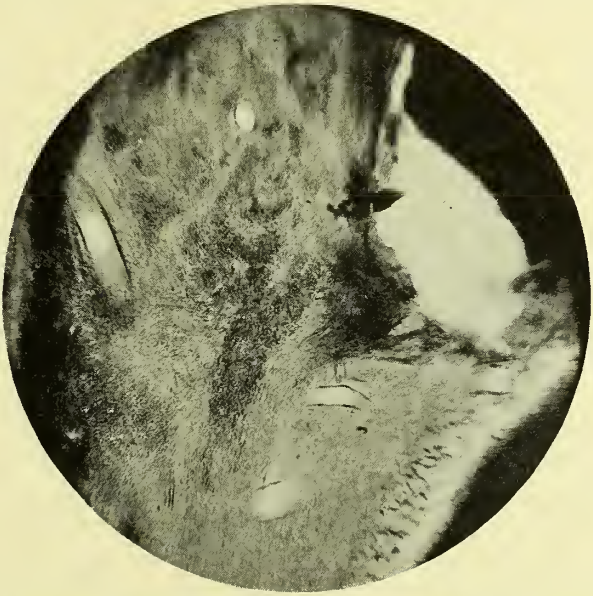


Fig. 878.—Calcareous degeneration of the pulp. (Courtesy of Dr. Harold K. Box.)

SECONDARY DENTIN AND TUBULAR CALCIFICATION

These manifestations have been frequently mentioned throughout this work, especially in the discussion of erosion, abrasion and slowly progressive caries. They may be considered as constructive protective processes, a laying down of new dentinal material in an effort of the pulp to defend itself against irritation.

By *tubular calcification* is meant an increased deposition of dentin on the inner walls of the dentinal tubules, thus narrowing their lumen and resulting in increased density of the area in which it occurs. It is due to mild forms of irritation of the dentinal fibrillae, producing stimulation of the odontoblasts to increased activity and resulting in a renewal of their functions in laying down dentin. The area affected usually presents a more translucent appearance, is more resistant to cutting instruments and is usually less sensitive than normal dentin. The translucent, highly burnished appearance found in cases of erosion and abrasion, and the eburnation of wide, open cavities in arrested caries is due to tubular calcification. Since the dentin increases in density with age, the condition may be attributed to a physiologic tubular calcification.

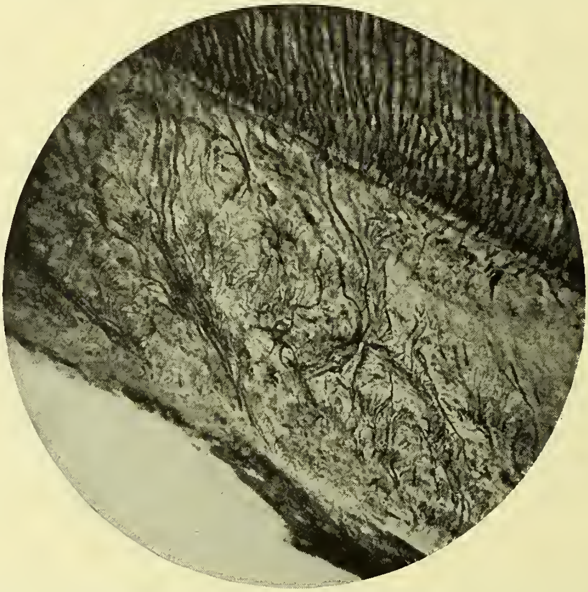


FIG. 879.—A form of secondary dentin. (Courtesy of Dr. Harold K. Box.)

The translucent zone of Tomes, found under caries, is a form of tubular calcification.

Adventitious or secondary dentin first presented itself to the student in the course in Dental Anatomy during the making of sections of natural teeth for the study of pulp chambers and canals. The depositions occur on the walls of the pulp chambers and canals, due to irritation and stimulation of the odontoblasts to renewed activity. As a result of the deposits, the size of the pulp chamber and canals gradually diminishes and recession of the pulp occurs. Reaction to thermal and electric stimuli decreases, owing to the layer of dentin interposed and to slow and gradual degeneration and choking of the pulp, the tissues finally succumbing and dying as a result of their effort to protect themselves against the attacking agencies. This may extend over a period of months or years, the chronicity of the reaction being characteristic. Figs. 879 and 880.

The causes are practically the same as those producing tubular calcification, although greater in degree. Additional factors in its production are metal fillings placed in too close proximity to the pulp, crowns on vital teeth and similar conditions producing thermal shock. Occasionally the pulp capping operation has been known to produce a deposition of secondary dentin and a resultant closing over of the point of exposure.

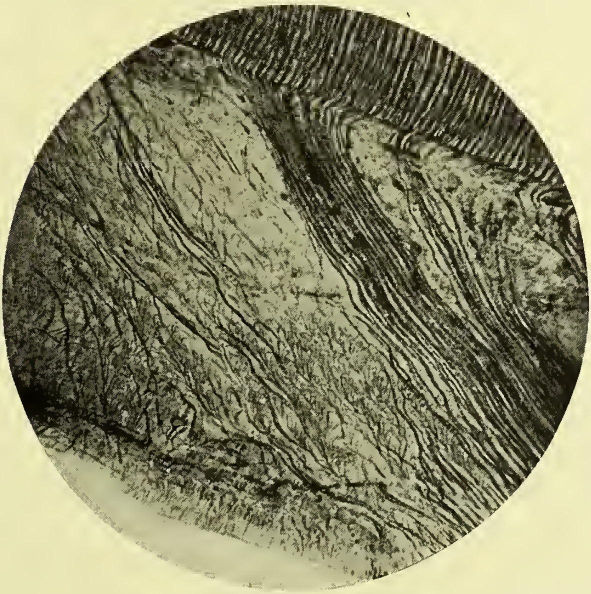


FIG. 880.—A form of secondary dentin. (Courtesy of Dr. Harold K. Box.)

Fractured roots have occasionally been repaired through depositions of secondary dentin and new cementum. Secondary dentin usually presents a translucent appearance, is often of a light or dark brown color, and is resistant to cutting instruments. Under the microscope, tubules may be found occasionally in the first layers deposited, but following a changed direction, while later layers become more homogenious and structureless, the tubules disappearing. Adventitious dentin formations may affect a single tooth or many, sometimes appearing in all the teeth of a denture. They may sometimes appear in conjunction with tubular calcification, the causes being similar. In progressive degeneration of the pulp, they also occasionally are found together with pulp nodules. Their presence often greatly interferes with root therapy and filling operations, root canals being occasionally almost or entirely obliterated. Resorption of the walls and enlargement of the pulp chamber have been reported, but are of rare occurrence.

The subjective symptoms of secondary dentin deposits are often vague. Reflex pains and neuralgia are common. Slow response to thermal and electric tests are characteristic. In the later stages, degeneration and death of the pulp occurs, with loss of pulp sensation. Tenderness of the tooth to pressure may occur from pericemental irritation. The X-ray will reveal deposits of any important size or extent, exhibiting diminution in the calibre of the pulp chamber or the canals.

TREATMENT OF VITAL PULPS

Avoidance of Pressure.—In cases of exposure (a minute opening through the wall of the pulp chamber), the vital pulp rebels against the application at the point of exposure of the slightest amount of pressure, so that during the treatment of these conditions, great delicacy of touch and the absolute avoidance of pressure is essential.

Aseptic Precautions.—Owing to the fact that the saliva and the decay present in cavities is highly infected with germs, whenever an exposure of the pulp occurs, these germs enter the pulp chamber and infect the pulp tissue, producing a septic condition of the part. The pulp is probably infected, then, in all cases of pulp exposure. There is also a possibility of these germs entering to the pulp through the layers of dentin in the floor of cavities, at the necks of the teeth, and through the cracks of the enamel, by way of the dentinal tubules, even in those cases in which the pulp is not exposed. The average diameter of the dentinal tubules ranges from 1.7 microns to 2.5 microns, which would admit ptomaines or toxins and germs without difficulty. Henrici and Hartzell[1] reported that pulps of normal teeth were free from germs, but that 42 to 46% of pulps in carious teeth and those affected with pericementoclasia were infected, although not exposed.

The organisms found in vital pulps are streptococci and staphylococci, particularly streptococcus viridans, as reported by Hartzell.[2] Heath[3] and Turner[4] of England have found similar organisms, as well as spirochetes and fusiform bacilli. Haden[5] reports that about 15% of cases of vital pulps examined by him exhibited the presence of germs. Certain of these germs are aerobic in character and will do no harm until air is admitted. Other forms are anearobic, highly infective and responsible for suppurative and putrefactive conditions. However, it must be recognized that the normal defenses of the body usually dispose of these germs in the pulp, as in other tissues of the body through phagocytosis and chemotaxis, as long as the vital resistive forces are maintained. Kurt H. Thoma reports similar findings in the Journal of Dental Research, Vol. VIII, No. 4, August 1928, page 529. In the conditions of suppuration and moist gangrene, highly infective micro-organisms are always present. In view of the above facts, it becomes necessary in treating diseases of the pulp to adopt measures to prevent as far as possible the entrance of germs, by absolutely and permanently excluding the saliva from the cavity, and by sterilizing all instruments, dressings, filling materials, and appliances used; or, in case the germs are already present, to destroy them by the application of non-irritating antiseptics and germicides. In the following pages, these measures will, for the sake of convenience, be designated "aseptic precautions."

CONSERVATIVE TREATMENT OF THE PULP

By conservative treatment is meant the institution of measures intended to maintain or restore the pulp in or to a normal state. The character of the procedure depends on whether the decay, when present, has extended to the pulp chamber, constituting the condition known as exposure of the pulp, or whether it has not produced this effect. There are, then, two forms of conservative treatment. If the pulp is not exposed, the treatment applied is known as Pulp Protection; if the pulp be exposed, the operation of Pulp Capping may be resorted to, under certain circumstances.

Pulp Protection.—Under "aseptic precautions" establish the outline form, remove the decay, make slight retentive form, and seal into the cavity with base-plate gutta-percha or cement, a small pledget of cotton moistened with an antiseptic and anodyne, such as eugenol or oil of cloves.

At the end of twenty-four or forty-eight hours, if pain is relieved, remove the dressing under "aseptic precautions," varnish the walls of the cavity, place a cement intermediate in position and fill. Dentinoid (Buckley) is also used by some for this purpose, covered with a cement intermediate.

Pulp Capping.—Owing to the danger of subsequent death of the pulp, this operation should be attempted only in exceptional cases. The usual indications for the operation are accidental exposures, teeth with incompletely formed roots, and very badly broken-down teeth, otherwise impossible to save. In all of these, the condition of the pulp must not have passed beyond the stage of arterial hyperemia, since it is usually impossible to restore pulps to a normal condition which have progressed beyond this state.

Conditions which affect the success of the operation are the condition of the pulp, condition of the mouth, age, and physical condition of the patient. Pulps should not, as a rule be capped, if they have passed beyond the stage of arterial hyperemia, and even this should first be relieved. Pulp capping operations usually are contra-indicated in unclean mouths and in the mouths of patients suffering from lowered vitality or systemic derangements interfering with the circulation; also in old patients whose recuperative powers are low.

The precautions necessary to successful pulp capping operations are: (1) relief of arterial hyperemia, (2) sterilization of the field of operation, and (3) avoidance of pressure. The substances recommended for capping pulps are a thin paste composed of one of the following remedies or mixtures, viz.:

1. Thymolized calcium phosphate and clove oil, eugenol or phenol compound (Buckley).
2. Zinc oxide and clove oil or eugenol.
3. Chloropercha.
4. Thymol melted over the exposure.

Of these, chloropercha is rarely used.

Technic of the Operation of Pulp Capping.—*First.*—Spray the mouth with an antiseptic, apply the rubber dam, sterilize the dam and teeth with tincture of iodin followed by alcohol and flood the cavity with an antiseptic.

℞	Phenolis	ʒ I (4.0 cc.)
	Aquae menthae piperitae	℥ VI (192.0 cc.)

Misce. Sig. Use wherever a mild, non-irritating antiseptic is indicated. (Buckley.)

Second.—Establish the outline form and remove the decay.

Third.—Sealin to the cavity for a week, an anodyne, antiseptic preparation, for relief of hyperemia, pain and irritation. Phenol compound (Buckley), eugenol, clove oil and campho-phenique are all recommended.

The formula of phenol compound is as follows:

Menthol	gr. XX (1.25 gm.)
Camphor	gr. XL (2.50 gm.)
Phenol. (U.S.P.)	ʒ III (12.00 cc.)

Heat the phenol and carefully add the others. (Buckley.)

Fourth.—Tease over the point of exposure and floor of the cavity, without pressure, a small amount of the capping material mixed to a creamy consistency; cover, and fill the cavity with a creamy mix of oxyphosphate of zinc cement. Allow the cement to remain for six months to a year, when, if the pulp has remained quiet, the outer layer of cement may be removed and a permanent filling inserted. Some operators prefer to carry the capping material to, and hold it over the exposure, with a concavo-convex metal disk of gold, in order to avoid pressure. The cap may be obtained ready prepared, or it may be cut and swaged on a soft block of wood to the proper shape and size. In the majority of instances it is not necessary.

The following report, indicating the result of 100 pulp-capping operations performed in the clinics of the New York University College of Dentistry under the supervision of Doctor William F. Medearis is of interest.

"The problem of exposed pulps has long been and still is one which offers a great deal of difficulty. Whether to attempt to save the pulp by capping, to do root therapy, or to extract the tooth is a question which presents itself daily to the general practitioner of dentistry. This article is the result of an effort to determine what cases of pulp exposure can be successfully capped.

"Just what is meant by the phrase 'successful pulp capping' is a debatable question. Is a pulp capping which prolongs the life of a tooth a year successful? Can one which saves the tooth until the patient is old enough for root therapy be called a success? Surely one which saves a sixth year molar until the permanent teeth are in position is successful. It seems to me that the term 'successful' is rather an ambiguous one. Therefore the term 'apparently successful' will be employed in this article to denote a pulp capping that has been done for several weeks and has given the patient no trouble and which responds normally to vitality tests.

"Experience has taught us that any serious interference with the circulation of the pulp will cause pulp death. We also know that if any decay is left in a tooth in which the pulp is exposed, degeneration of the pulp follows. In the cases reported here, only those which were considered most favorable were undertaken. If the hemorrhage from the pulp was severe, no attempt was made to cap the pulp. If there was any decay remaining in the cavity and the pulp was entered, either root therapy or an extraction was ordered. No cases were undertaken unless the rubber dam was in position. Only in those cases of accidental exposure after the removal of decay with the rubber dam in place was any effort made to save the pulp by capping it.

"This is a report of 100 cases extending over a period of a year. The following procedure was carried out in all exposures made under the conditions outlined above. A small crystal of thymol was placed in the cavity slightly to one side of the exposure. A ball burnisher was then warmed and touched to the thymol crystal, which immediately melted and flowed over the exposed horn of the pulp. After the thymol had crystallized, the margins of the cavity were lightly scraped to remove any thymol that might have flowed over them. A putty like mixture of eugenol and zinc oxide was then introduced into the cavity. With a cotton pellet this was tamped into position, using very little pressure. The cotton absorbed some of the excess liquid from the eugenol-zinc oxide mix. A thin mix of cement was then inserted into the cavity. This was made as soft as possible, so as not to cause any pressure on the exposed portion of the pulp. After this cement hardened the remainder of the cavity was filled with a second harder mix. The rubber dam was then removed and any traumatic occlusion on the tooth was remedied. The tooth was then tested with an electric vitality tester, hot base-plate gutta-percha and cold water. The reaction to these stimuli was noted and a comparison made with the same tooth on the opposite side of the mouth or in the opposite jaw if its mate were missing. An accurate record was made of all this and the patient was dismissed for a month or two, depending upon age. The younger the patient, the sooner he was told to return.

"When the patient returned, he was questioned about the behavior of the tooth in the interim. If no history of pain was reported the tooth was given a vitality test and also a heat test with hot base-plate guttapercha and cold water. The reaction of the tooth at this time was compared carefully to the reaction at the time of capping. It was also compared to the reaction of the same tooth on the other side of the mouth or in the opposite jaw. If the response to these stimuli was about the same as the response at the time of capping and as the response of the opposite or opposing tooth, part of the cement was removed and a permanent filling inserted. Where the reaction of the tooth was violent and it was hypersensitive to all stimuli, the patient was dismissed for another month, provided there was no history of aching or pain on percussion. In cases which showed a sluggish response to stimuli, as compared to the response at the time of capping and compared to the opposite tooth, it was assumed that some degeneration of the pulp had taken place, and either root therapy or extraction was ordered.

"Out of 100 cases whose records were kept accurately, the following results were obtained:

"Thirty-seven cases were outright failures: That is, the history of the case from the time of capping until the patient returned was too unfavorable to warrant the insertion of a permanent filling. Disease of the pulp was definitely manifested.

"About eight cases which seemed all right a month after capping were filled permanently, only to flare up after filling and result in loss of the pulp or the tooth.

"Several cases showed hypersensitiveness considerably above normal upon return, but not acutely enough to take decided action at that time. They were dismissed and told to report again in another month. Sometimes they had to be sent away for a third month before the reaction was definitely favorable or unfavorable. Of these, only three had permanent fillings inserted. Pulp death resulted eventually in the other.

"At the present writing there are only 47 out of 100 cases tried which are apparently successful. Permanent fillings have been in these teeth in varying periods of from six weeks to nine months. They all responded normally when filled. Some of them have been tested since filling, though most of them have not. The patient was told to come in immediately if any trouble developed. The fact that the patients have not returned, though showing that no trouble has been experienced by them, does not prove conclusively that the pulps of these forty-seven teeth are still living. And they may all have trouble and come in within the next few weeks. However, having no knowledge to the contrary, I shall consider these cases as apparently successful, having explained above what the term 'apparently' means.

"In conclusion, let me say that most cases of exposed pulps mean death to the pulp. Only in young individuals and in those teeth from which all decay has been removed under the most sanitary conditions can we hope for a reasonable degree of success."

Advantages in Maintaining Vitality.—The advantages in maintaining the vitality of the pulp are:

First.—Avoidance of root-canal work and the danger of infection in the apical space arising later from imperfect canal operations.

Second.—The pulp is the formative organ and the organ of nourishment for the dentin, and when it is removed, the tooth does not completely develop and is more subject to pathologic processes.

Third.—When the pulp is lost, the enamel becomes more brittle and more subject to fracture and decay.

Fourth.—Caries, arising later in the tooth, progresses more rapidly in non-vital dentin, a fact clinically recognized and attributed by some to loss of its normal vital resistive powers.

RADICAL TREATMENT OF THE PULP

By radical treatment of the pulp is meant its removal after it has been previously anesthetized.

The following conditions frequently necessitate the removal of the vital pulp:

First.—Exposure in the presence of infection, of pulps apparently normal or affected with arterial hyperemia.

Second.—Unfavorable reactions following the operation of capping the pulp.

Third.—Venous hyperemia, inflammation, suppuration, degeneration and invasion of the pulp by pathogenic micro-organisms, as a result of caries and smilar conditions.

Fourth.—Mechanical irritation from abrasion, thermal changes, metallic fillings, rapid regulation, excessive grinding, and similar causes.

Fifth—Calcific deposits in the pulp, or on the walls of the pulp chamber.

Sixth.—Crowning and extensive filling operations, where additional anchorage is required, or proper preparation cannot otherwise be accomplished.

Seventh.—Pericementoclasia, where additional anchorage for splints is desired, where the pulp is diseased, or where the affected teeth are hypersensitive.

Therapeutic Measures.—The conditions essential to a successful result in the removal of pulps are: (1) establishment and maintenance of asepsis, (2) preservation of the color of the tooth, and (3) thorough opening and filling of the canal.

The various methods which have been used for the painless removal of pulps are: Pressure anesthesia, the high-pressure syringe, cataphoresis, conductive or infiltration anesthesia, application of nervocidin, or devitalization with arsenic trioxid, after which the pulp is extirpated.

The use of the high-pressure syringe has been abandoned. The Meyers and the Jewett-Wilcox were prominent forms of syringe for this purpose. This was used where there was no exposure present, and consisted of the injection of cocaine hydrochlorid or procaine solutions, through the dentinal tubules into the affected pulp. The cataphoric method of anesthetizing and removing pulps is no longer advocated at present, owing to the dangers and time required. By means of the cataphoric apparatus, an electrc current, slowly and gradually increased in voltage, forced the anesthetic solution through the tooth structure into the pulp. Anesthetization by nervocidin and devitalization by arsenic trioxid consisted in sealing into the cavity a small amount of nervocidin or arsenic trioxid for twenty-four hours, when the pulp was anesthetized or devitalized, and painlessly removed. The use of these remedies is practically abandoned for this purpose, owing to the dangers involved.

For anesthetization of vital pulps before removal, nerve-blocking or infiltration anesthesia is now considered the method of choice. In cases where anesthetization of the pulp is incomplete with these methods, they may be carefully followed with pressure anesthesia to produce complete loss of pulp sensation. Pressure anesthesia should be avoided wherever possible, on account of the danger of forcing infected material through the apical foramina, with resultant infection of the periapical tissues. Its use is prohibited in cases of suppurative pulpitis for this reason.

Sterilization of the cavity before pulp removal is important, because it is necessary to avoid further infecting the pulp and apical tissues during the subsequent procedures. In addition to the application of the dam and sterilizing agents, all instruments, dressings, and appliances should be sterilized. Coagulating agents, such as full strength phenol, should be avoided for sterilizing cavities, preceding the operation. Use for the purpose a 10% solution of formalin or better a 50% solution of thymol in alcohol. Clarence J. Grieves recommended for this purpose one part beech-wood creosote in ten parts clove oil, sealed into the cavity for two or three days preceding the operation.

The Operation of Pressure Anesthesia.—Procain or novocain has the property of temporarily depriving the tissues of sensation. When forced into the tissues of the pulp, that organ is for a time anesthetized, when it may be painlessly removed.

In cases of incomplete anesthetization of the pulp with infiltration or nerve-block anesthesia, place a small pellet of novocain hydrochlorid or procain in the cavity, and, after adding a drop of sterile water, when it will be dissolved, cover it with a small pledget of cotton.

Cut a piece of soft unvulcanized rubber, of a size sufficient to fill the cavity, and with a large amalgam plugger or smooth burnisher, slowly and gradually apply pressure, thus forcing the solution into the pulp, constantly maintaining pressure until it does not elicit pain, when the rubber and cotton are removed and the pulp is ready for extirpation (removal). The rubber is placed so that it acts as a washer and prevents the backward flow of the solution. The technic of removal of pulps and opening pulp chambers and canals is fully described in Chapter XXVIII.

Adrenalin Chlorid and similar preparations in combination with novocain should be avoided for pressure anesthesia, on account of the danger of being forced into the apical space, temporarily constringing these tissues, and resulting later in secondary hemorrhage and traumatic pericementitis. Hemorrhage following pulp removal is sometimes likely to occur. In mild cases, swab the canal with alcohol, sterile water, or peppermint water. Do not use peroxid of hydrogen, on account of its tendency to unite with the iron of the hemoglobin of the blood, form ferric hydroxid, enter the tubules and produce staining. In the graver cases, use alcohol, phenol compound, formocresol, or adrenalin chlorid. Agents containing tannic acid or glycerite of tannin should be avoided in root canal work on account of their tendency to unite with the iron of the blood, form a black iron tannate, and produce staining.

The color of the tooth should as far as possible be preserved during pulp treatment. The color of the tooth depends largely upon the array of colors in the dentin, which are reflected through the enamel, and not on its vitality or non-vitality. This being the case, the saliva should be excluded at once and never again be allowed to enter, since it will carry infection and discoloring agents. In addition, all colored drugs and drugs capable of producing staining should be avoided. For the same reason, all remains of blood and pulp remnants should be perfectly removed.

Anodyne, non-irritating, antiseptic preparations, such as phenol compound, (Buckley), thymophen (Kirk), thymocamphen (Prinz), eugenol, clove oil, campho-phenique, or thymol in alcohol may be sealed in the canal for 24 to 48 hours following pulp removal, to give the tooth physological rest and to assure the prevention of periapical tenderness, irritation and possible infection, before filling of the canals.

Immediate filling of the root canals should usually be avoided after removal of vital pulps, for the following reasons:

1. The apical tissues frequently are still anesthetized, with the result that there is no way of knowing whether the apical connections of the pulp are completely severed and all pulp tissue removed.

2. Tearing away of the pulp from its apical connections produces irritation, which should first be allowed to subside.

3. The danger of secondary hemorrhage with consequent formation of a blood clot is always present.

Bibliography

1. Hartzell, T. B. and Henrici, A. T.: Jour. Amer. Dent. Assoc., 1913, 1914, 1915.
2. Hartzell, T. B.: Jour. Nat. Dent. Assoc., 1920, p. 375 and 1921, p. 213.
3. Heath, J. S.: British Dent. Jour., 1921, pp. 239–768 and 1924, p. 558.
4. Turner, J. G.: Royal Society of Medicine (Odon.) 1919, p. 104.
5. Haden, R. L.: Jour. Infect. Dis., 1926, p. 486.

Buckley, J. P.: "Dental Materia Medica and Therapeutics," P. Blakiston's Son & Co., Philadelphia.

Prinz, Herman: "Pathology of the Diseases of the Soft Tissues of the Mouth," Lea and Febiger, Philadelphia.

Davis, O. DeForrest: Pulp conservation in restorative dentistry, Jour. Amer. Dent. Assoc., vol. XV, no. 12, Dec. 1928, p. 2259.

Crane, Arthur B.: Diagnosis preceding root canal treatment, Jour. Amer. Dent. Assoc., vol. XV, no. 2, p. 236.

Coolidge, Edgar D.: Pulp pathology and treatment problems, Jour. Amer. Dent. Assoc., vol. XII, no. 9, Sept. 1928, p. 1623.

Best, Elmer S.: Relation of deep-seated caries to pulp canal involvement, Jour. Amer. Dent. Assoc., vol. XIV, no. 10, Oct. 1907, p. 1859.

Thoma, K. H.: The infected vital dental pulp, Jour. Dental Research, vol. VIII, no. 4, Aug. 1928, p. 529.

Bunting, R. W.: "Oral Pathology," Lea and Febiger, Philadelphia, 1929.

Moorhead and Dewey: "Pathology of the Mouth," W. B. Saunders Co., Philadelphia, 1925.

Endellman, Julio: "Dental Pathology," C. V. Mosby Co., St. Louis, 1927.

Cahn, Lester R.: Effects of the degenerating dental pulp, Dental Items of Interest, Nov. 1927.

Coolidge, Edgar D.: Heterotopic ossification in the pulp, Jour. Amer. Dent. Assoc., May 1927, p. 821.

CHAPTER XXVII

DISEASES OF THE DENTAL PULP (*Continued*)

VITAL RESISTANCE OF TEETH—GANGRENE OF THE PULP—DISEASES OF THE PERIAPICAL TISSUES—TREATMENT OF NON-VITAL PULPS AND PERIAPICAL DISEASES

VITAL RESISTANCE OF TOOTH STRUCTURE

When the pulp loses its vitality, or is removed for any cause, the enamel and dentin probably are deprived of their main source of nutrition. This, however, is not true of the cementum, which still receives nourishment from its lining membrane, the pericementum, and thus retains its vital connections with the supporting tissues. It may thus be seen that the phrase, "dead tooth," is a misnomer, and, in the majority of instances, should not be used, since it is frequently liable to lead to a misconception of the functions and capacity for continued usefulness of a pulpless tooth. Figs. 881, 882 and 883. Vital teeth are believed by many investigators to be capable of offering a certain amount of resistance

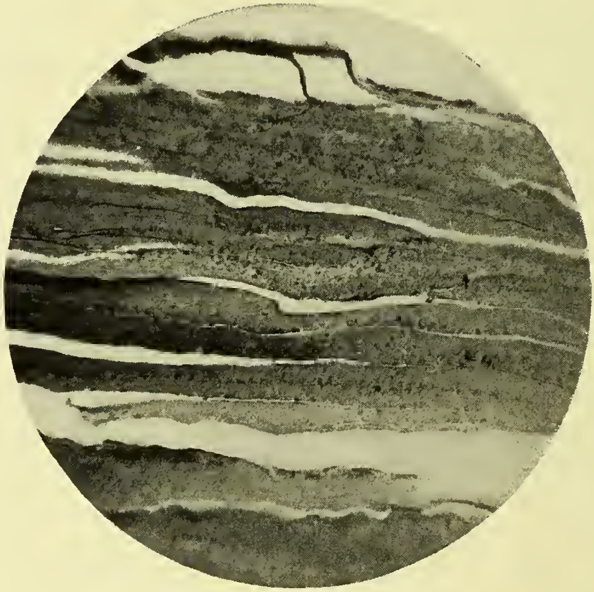


Fig. 881.—Cemental lamellae. (Courtesy of Dr. Harold K. Box.)

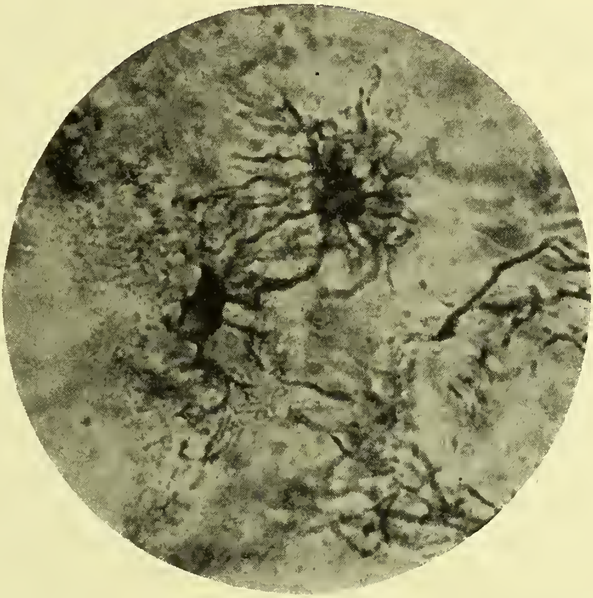


FIG. 882.—Cellular cementum of apical third of the root, showing lacunae and canaliculi. (Courtesy of Dr. Harold K. Box.)

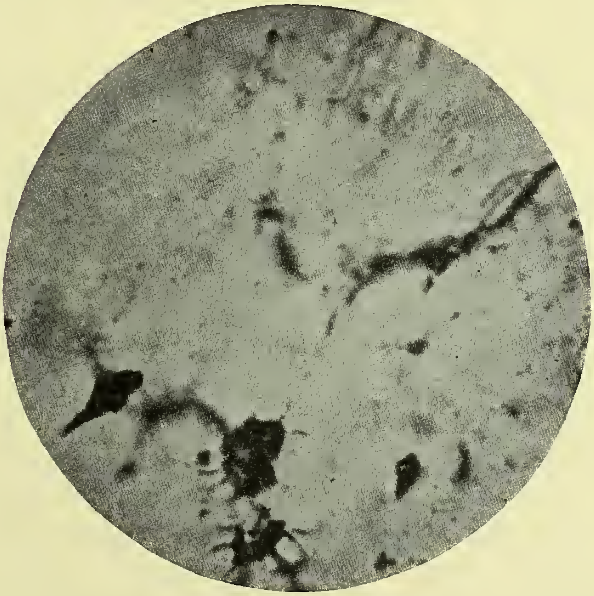


FIG. 883.—Dentino-cemental junction at upper right. Shows spindle shaped end of dentinal tubule extending into cementum and communicating with a cemental lacuna in lower center. (Courtesy of Dr. Harold K. Box.)

throughout their periods of usefulness, to the inroads of pathologic processes. The following evidence is offered in support of this statement, viz.:

First.—The pulp is the formative organ of the dentin, and, after tooth formation is complete it remains to furnish nourishment via the dentinal tubules to this structure. The dentinal fibrils are bathed in a serous exudate of living protoplasm, which is exuded from the trophic pulp. On the life of the pulp largely depends the existence and welfare of the tooth.

Second.—The dentinal fibrils in some instances extend into the enamel. This is considered by some as an abnormality, but the condition is found frequently enough to be taken into consideration.

Third.—When the tooth is subjected to abnormal influences, such as caries, abrasion, erosion, and other similar conditions, the pulp responds in the form of a vital impulse and interposes a wall of resistance against the attacking agencies in the form of a transparent zone, tubular calcification or secondary dentin. Hypersensitive dentin is also the result of vital action.

Fourth.—These phenomena are never found in pulpless teeth.

Fifth.—Clinical evidence demonstrates that devital teeth decay more rapidly than vital ones. The dentin partially loses its strength, elasticity and translucency.

Sixth.—When the pulp of a tooth is removed for any cause, the enamel is much more subject to cracks, fractures, splitting off from the surface of the dentin, and rapidly progressing caries.

Seventh.—The enamel, dentin, and cementum are capable of staining, either from within or without, by staining reagents, and the rapidity of staining is much greater in dead than in living teeth. The enamel is slightly receptive to staining agents when vital, but much more so when non-vital.

Eighth.—Causch, Von Buest, Bödecker, Heitzman, Klein, Tomes, Abbott, Von Ebner, Andreson, Morgenstern and others demonstrated the presence of living protoplasm in various forms in the enamel, indicating the probability that this substance is not completely out of the pale of nutrition. Chemical analysis of this protein material by William J. Gies,[1] C. F. Bödecker,[2] E. W. Fisch[3] and others reveals according to these investigators that at least some of it is keratin.*

Ninth.—Woods, Causch, Miller, Kirk, Gaskill, Hopewill-Smith, Burchard and others have reported cases of resorption of the enamel and dentin from within, via the pulp, which could occur only through vital action. In some of these cases the resorbed areas have later been filled in by new depositions, via the pulp.

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* Cape and Kitchin[4] were unable under polarized light to discover keratin in enamel.

Tenth.—In pregnancy, rickets, osteomalacia, and similar conditions, the bones and teeth are subject to retrograde metamorphosis and absorption of their contained lime salts, via the blood stream. The teeth are markedly more subject to caries in these conditions.

Eleventh.—In sickness, convalescence, lowered vitality from any cause, the teeth are more subject to decay, regardless of the regular hygienic care which may be given them. The condition is due in many instances, especially in rickets, osteomalacia, gout and diabetes, to the fact that not only is the resistance of the vital protoplasmic contents of the teeth lowered, but also that in these conditions, according to J. H. Kellog, there is an excess of ammonium chlorid formed in the blood, which, reaching the vessels of the pulp, produces a dissolution or softening of the hard tissues of the teeth.

Twelfth.—Black to the contrary, Pickerill and others have demonstrated an increase with age, in the amount of calcium salts in the enamel, as well as a marked difference in the total amount in all of the tooth tissue in the so-called hard and soft teeth. This necessarily must be due largely to vital functions or activities.

IMPORTANCE OF RETENTION OF VITAL AND NON-VITAL TEETH

It may thus be perceived that it is important to maintain the vitality of the pulp in every instance where this is possible. However, its removal, as previously stated, does not necessarily result in the leaving in position in the mouth of a dead organ, since vital relationships are still maintained in the cementum by way of the peridental membrane. A non-vital tooth is not then a menace per se to the health of the individual, if it be given proper treatment through the thorough removal of all septic material, and if the canals be hermetically sealed against the entrance of infection from without or through lateral or accessory canals, or the apical foramena. Figs. 883 to 886. If these procedures be properly performed, a non-vital tooth (so-called) may, in the majority of instances, be restored to prolonged periods of usefulness. It is true that its normal resistance, as far as the enamel and dentin are concerned, is probably lost, that it is more subject to caries, fractures and other pathologic disturbances, and that it is not capable of subjection to the excessive stresses to which vital teeth are subject; but in this condition it is usually a far superior functioning piece of mechanism than is an

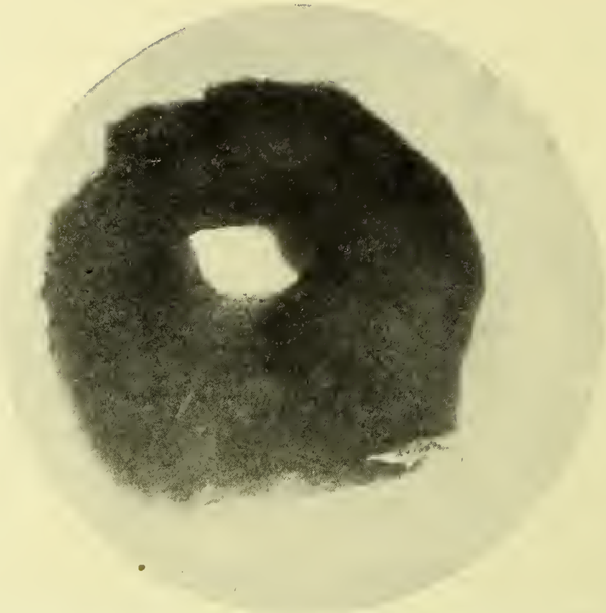


FIG. 884.—Transverse section of a root in the apical third, showing root canal. (Courtesy of Dr. John B. Stein.)

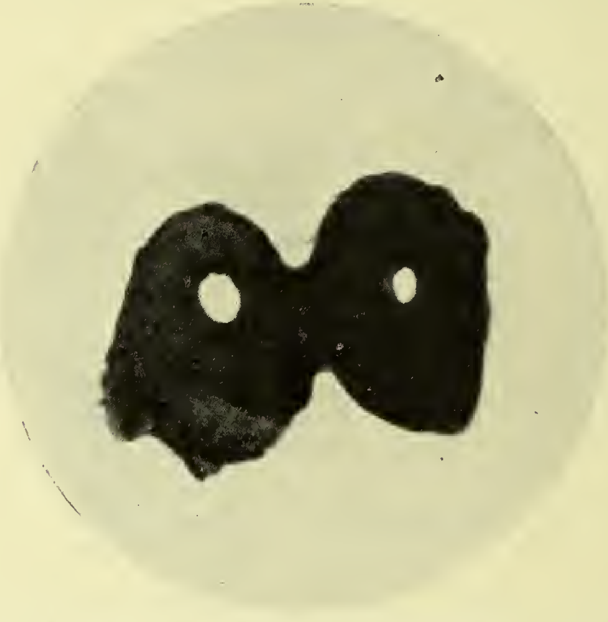


FIG. 885.—Transverse section near the apex of a double rooted tooth, showing two root canals. (Courtesy of Dr. John B. Stein.)

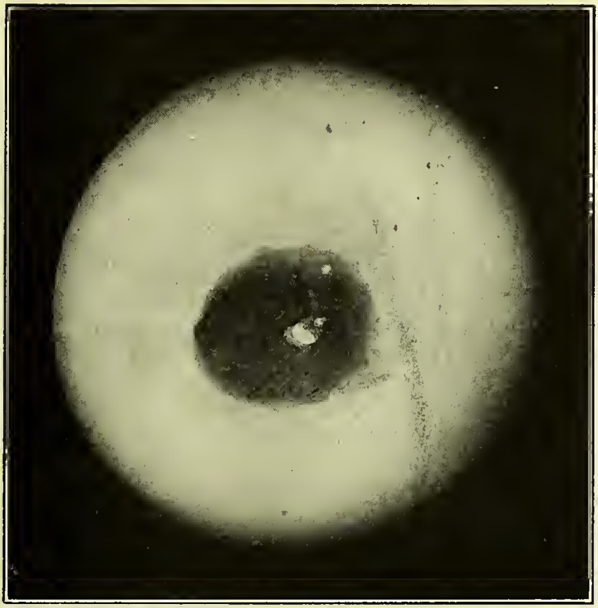


FIG. 886.—Multiple foramina at root apex. (Courtesy of Dr. J. B. Stein.)

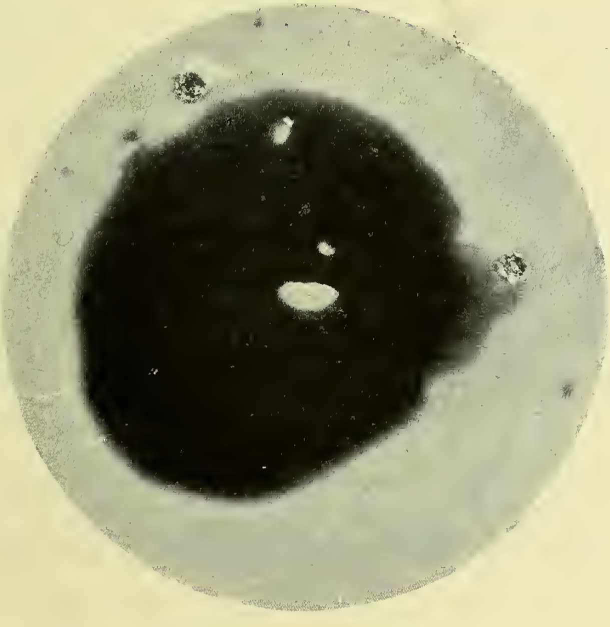


FIG. 887.—Transverse section near the apex of a single rooted tooth, showing three foramina. (Courtesy of Dr. John B. Stein.)

artificial substitute. Consequently, every effort should be made to retain teeth of this character, for obvious reasons. Too much stress, however, cannot be laid on the importance of the removal of all infection, through an aseptic technic, proper sterilization and thorough filling of the root canal, on account of the danger of infections arising later in

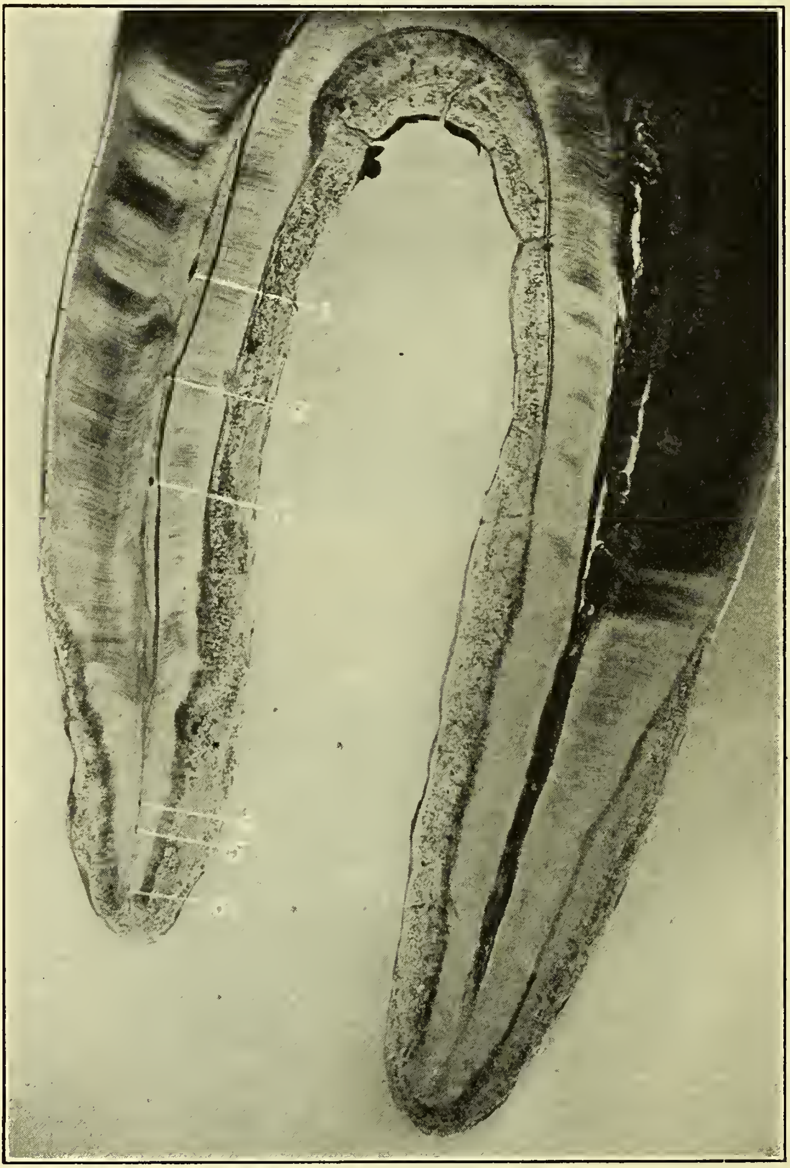


FIG. 888.—Two roots of a lower molar. One root shows six small diverticula or lateral canals springing from the main canal. (Courtesy of Dr. John B. Stein.)

the apical portion of the root and the apical space and producing a local fucus, which may subject the patient to grave systemic disturbances. This phase of the subject is more fully discussed in the subsequent chapter. Fig. 888.

DRY GANGRENE OF THE PULP

Causes and Symptoms.—In case death of the pulp occurs in the absence of putrefactive germs, dry gangrene is produced, a condition in which the pulp remains as a dry, odorless, shrivelled mass, insensitive, unaffected by temperature changes, and likely to cause discoloration of the tooth. The disease may continue for an indefinite time without symptoms, but is always a menace, on account of the danger of the presence or later entrance of putrefactive germs and the production of moist gangrene, with subsequent alveolar abscess.

The presence in the tissue of aerobic micro-organisms is always a possibility. On the admission of air through a cavity or on surgically opening into the pulp chamber, these may spring into sudden activity and produce grave consequences, through infection and rapid transformation of the case into one of moist gangrene. It may readily be understood that the condition offers an inviting field for the location of suppurative and putrefactive bacteria. Cases of this nature often spring into acute activity soon after opening, either through the action of aerobic bacteria already present, the admission of air or the introduction of infective germs on improperly sterilized instruments and dressings. Also there is the possibility of the entrance of putrefactive germs, present in the air, alone, soon after instrumental opening into the pulp chamber. These possibilities should constantly be borne in mind during the treatment of these cases. Since pain and subjective symptoms are absent, cases are occasionally accidentally discovered during routine examinations, from observance of lack of response to thermal and electric tests, loss of normal translucence of the tooth under reflected light, or discoloration. Often a history of trauma may be obtained, or the presence of traumatic occlusion or excessive occlusion of a filling may be discovered as a possible cause. Some form of mechanical trauma, such as a blow or fall, thread biting, nut cracking, undue separation or too rapid orthodontic movement is the most frequent cause. Others occasionally concerned are the presence of hypercementosis, causing constriction of the apical foramina, secondary dentin, or pulp nodules producing pulp exhaustion, aseptic death following pulp capping operations, etc. Fig. 889.

Treatment of Dry Gangrene.—The treatment consists in removal of the pulp without pressure under aseptic precautions, with immediate root filling; or better, after removal, of the sealing in the canals for a few days of a bland antiseptic, such as phenol compound, 5% formalin solution, or thymol in alcohol, following which they are ready for filling. As a precautionary measure, filling usually should be postponed until a second sitting.

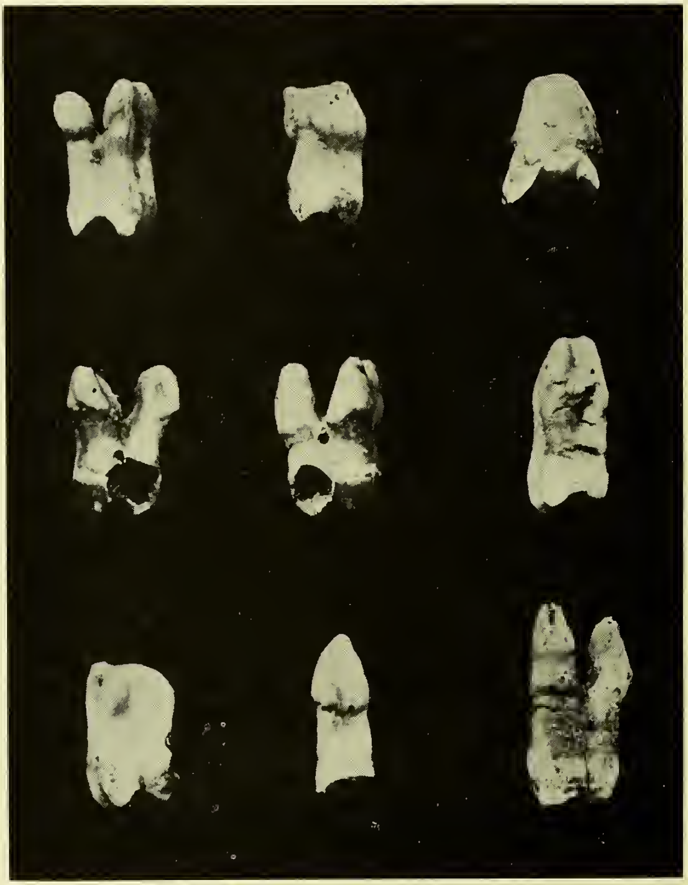


FIG. 889.—Hypercementosed roots.

MOIST GANGRENE (PUTRESCENCE)—PUTREFACTIVE DECOMPOSITION

Any of the already mentioned causes of hyperemia, pulpitis, suppuration, the chronic inflammations and degenerations, or of dry gangrene may be concerned in the ultimate production of putrefactive decomposition of the pulp. The essential feature is the entrance of putrefactive bacteria. Moist gangrene is sometimes a sequel of dry gangrene, as previously stated. Fig. 890.

Chemistry, Bacteriology and Pathology.—The chemistry and pathology are the same as that incident to putrefaction of other tissues. Four clinical types of putrefactive decomposition of the pulp may be observed, viz.: (1) teeth apparently sound, (2) teeth with open cavities of decay, (3) teeth with a filling in position, but canals untreated and (4) teeth with imperfectly or improperly treated and filled canals. Gangrenous pulps usually present mixed infections of germs common to the oral cavity, such as bacilli, streptococci, staphylococci, spirochetae and fusiform types. Prominent among these may be mentioned the Bacillus gangrenae pulpae of Arkovy, the Bacillus mesentericus of Sieberth, Bacillus pyoceaneus, Streptococcus Viridans of Miller, Goadby and Hartzell and Staphylococcus pyoceaneus aurius, albus and citreus. Rickert,[5] Lyons,[6] and Hadley[7] report the frequent presence of Strep. Fecalis, S. salivarius and S. mitis.

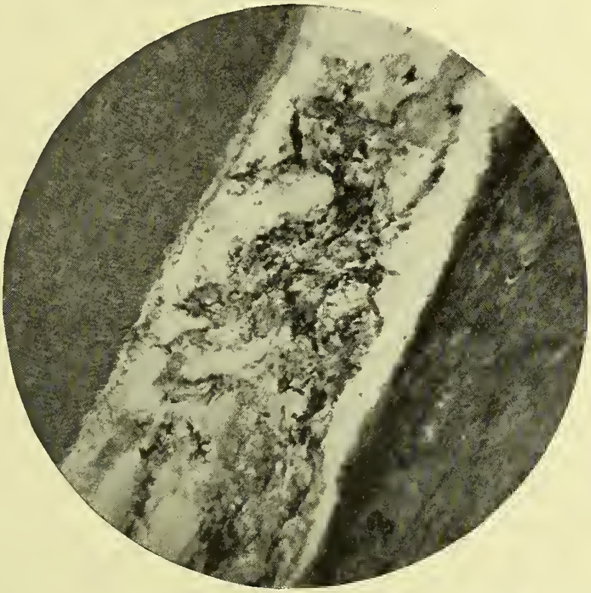


FIG. 890.—Necrotic pulp. (Courtesy of Dr. Harold K. Box.)

A knowledge of the chemistry of putrefactive decomposition of the pulp is important, in order that the chemical changes taking place and the new chemical compounds being formed during its progress may be known, so that the proper remedies may be intelligently and rationally applied in the treatment of the condition.

The chemical composition of normal pulp tissue consists of (1) proteins, (2) carbohydrates and (3) fats. (1) Proteins or albuminous substances contain principally the elements, C, H, O, N, S and Fe in their molecule, and break down or are destroyed through the process of putrefaction. (2) Carbohydrates contain C, H, O in their molecule—always six atoms of C or multiples of six, with H and O in proportion to form water. These substances are broken down through the process of fermentation. (3) Fats consist principally of palmitin, olein and stearin, contain C, H, O in various proportions, and are decomposed through a process of saponification by alkalies, or ferment in an alkaline medium.

As already stated, the entrance of putrefactive germs, either through an open cavity, from a layer of imperfectly-removed infected dentin, via exposed dentinal tubules, a leaky filling, or through the circulation is necessary to produce putrefaction of pulp tissue.

In a study of the chemistry of putrefactive decomposition of the pulp, we are concerned especially with the proteins and fats, since the carbohydrate material does not putrefy. The germs of putrefaction act on the above unstable compounds and break them down (an analytic process) into new compounds of simpler nature. They first form certain intermediate products, and finally resolve these into certain end products of a still simpler molecular composition.

The chief **intermediate products** formed are:—

First.—Peptones and allied substances.

Second.—Ptomains or animal alkaloids, of which putrescin, cadaverin and neuridin are the principal ones. Ammonia (NH_3) or derivatives of ammonia are later formed from all of these. Neuridin is almost harmless, but the other two, if forced through the apical foramen, produce inflammation, suppuration and abscess formation in the tissues of the apical space.

Third.—Amino-acids (the principal ones being tyrosin and leucin), and the amins (methyl, ethyl and propyl). Ammonia and its derivatives are formed from these, and also fatty end products.

Fourth.—Aromatic products, such as indol, phenol and cresol.

The **end products** formed from the above intermediate substances are chiefly water (H_2O), carbon dioxid (CO_2), acetic acid ($HC_2H_3O_2$), ammonia (NH_3), hydrogen sulfid (H_2S) and a semiputrid substance, largely fats. Of these substances, the most harmful are ammonia gas and hydrogen sulphid, of which the former is present in much larger amounts.

The putrefactive process is not confined to the pulp chamber and canals. The dentinal fibrillae are broken up, as are also the hemoglobin and other constituents of the blood, with the result that the tubules also are filled with the intermediate and end products, as well as with coloring matters and other substances.

Symptoms.—The clinical symptoms of putrescent pulp are characteristic and consist chiefly of opacity and discoloration of the tooth, the characteristic odor of putrefaction, bad taste in the mouth in open cases and lack of response to vitality tests. In closed cases, pain may occur from confinement of the gases of putrefactive decomposition. Application of heat will also be likely to produce expansion of gases, pressure on the tissues of the apical space and resultant pain. On exposure and opening into the pulp chamber, the putrescent material may be evidenced in the form of a yellowish, or dark, jelly like mass. In the later states, partial or complete liquefaction may be present. In open cases the chamber and canals may be partially or completely empty, indicating total destruction of their contents. Death may be present in the bulbous portion, with the radicular portion still vital. In multi-rooted teeth, moist gangrene in one root and inflamed vital tissue in others may be present. Conditions of this nature will often obscure the diagnosis, owing to variations in thermal and electric reactions incident to the combined presence of vital and non-vital tissue. In other cases, death *en masse* of the entire pulp may occur. The characteristic odor, together with the case history and objective symptoms will usually confirm the diagnosis without difficulty. The danger of passage through the apical foramen of the intermediate and end products, together with germs and their exudates is always present, with the consequent tendency to the formation of alveolar abscess.

THERAPEUTIC TREATMENT OF PUTRESCENT PULPS

Numerous therapeutic remedies have been used from time to time for the treatment of putrescent pulps. Prominent among those at present advocated are Formo-cresol (Buckley), Sodium dioxid (Kirk), Kalium-Natrium (Schrier), Dichloramin T and Chlorozane (Prinz).

Formo-cresol.—This is a solution of equal parts of formalin and cresol, first advocated by J. P. Buckley. According to his theories, important chemical reactions occur during the use of this combination. The method of its use is herewith given.

1. Under aseptic precautions, establish the outline form, remove the decay and make the cavity retentive.

2. Open the pulp chamber and remove the bulbous portion of the pulp.

3. Seal into the pulp chamber, by means of base-plate guttapercha or cement, on a pledget of cotton, a mixture of equal parts of formalin and cresol, known as formocresol.

4. At the end of from twenty-four to seventy-two hours, depending on the virulence of the case, take out the dressing under aseptic precautions, and remove the remainder of the pulp from the canals.

5. Place in each canal, and also in the pulp chamber, absorbent points and cotton containing the formocresol mixture, and seal the cavity as before.

6. After an interval of from twenty-four to seventy-two hours, remove the dressing under aseptic precautions, and, if all evidences of putrefaction are destroyed, fill the canals.

The Chemical Reactions occurring between the intermediate and end products and the formalin are interesting. The formalin, liquor formaldehyde, unites chemically with them and forms new, odorless and non-infective compounds of a harmless nature. It also destroys the micro-organisms. Formalin unites with ammonia (NH_3) and forms urotropin; also with hydrogen sulfid (H_2S) forming methyl alcohol and sulphur. It also unites with the ptomaines, cadaverin, putrescin and neuridin, forming new, inodorous compounds. In this manner the two gases being formed in largest amounts and giving the most trouble, as well as the poisonous ptomaines, are transformed into non-irritating, non-poisonous liquids and solids. Potent reactions also occur with the other intermediate products formed.

Cresol is used because (1) it is a good disinfectant, much stronger than phenol, thus destroying the germs and odors; (2) it readily mixes with formalin in all proportions and makes a clear solution; (3) it is anodyne and modifies the irritating effects of the formalin, being used for that reason, as well as from the fact that it dilutes the solution; (4) it saponifies the fats and fatty acids, transforming them into antiseptic soaps.

Sodium Dioxid.—Sodium dioxid, NA_2O_2, introduced by Edward C. Kirk, in 1893, is a yellowish-white powder, containing a large amount of nascent oxygen, on which it depends for its efficacy. It deteriorates very rapidly on exposure to the air; consequently it must be kept tightly sealed when not in use. It must be handled very carefully, on account of the danger of an explosion if brought near a flame or mixed carelessly with water. It is a strong caustic, hence the importance of preventing contact with the soft tissues. It is better handled with gold, platinum or glass instruments, on account of its corroding action on steel. The tooth should be isolated with a rubber dam gnd carefully ligated, the use of steel clamps being avoided on the tooth to be treated. A paste may be made by mixing the preparation with chloroform on a glass slab, to be carried into the pulp chamber and canals on broaches, preferably of gold or platinum; or a small amount of the powder may be laid on the glass slab and a few drops of distilled water placed to one side. Then the broach may be moistened in the water, drawn quickly through the powder and instantly carried into the canals, when effervescence ensues, due to the oxidizing and destructive effect of the preparation on the organic contents. The procedure is repeated until all of the pulp tissue

TABLE SHOWING CHEMICAL CHANGES OCCURRING DURING PUTREFACTIVE DECOMPOSITION OF THE PULP AND ACTION OF FORMOCRESOL ON THE INTERMEDIATE AND END PRODUCTS

I. *Chemical Composition of Normal Pulp Tissue.*
  1. Nitrogeneous Compounds
    A. Proteins or Albuminous Substances

      C, H, O, N, S (Fe-P)
      (Putrefy)
  2. Non-nitrogenous Compounds
    B. Carbohydrates
      C, H, O
      (Ferment)
    C. Fats
      C, H, O
      Palmitin
      Olein
      Stearin
      (Saponify or ferment in an alkaline medium)

II. *Intermediate Products*
  (Produced by action of germs)
  1. Peptones, etc.
  2. Ptomaines (Animal alkaloids)
    A. Putrescin
    B. Cadavarin
    C. Neuridin
  3. Amino-Acids (Fatty Acids)
    D. Tyrosin
    E. Leucin
  4. Amins
    F. Methyl
    G. Ethyl
    H. Propyl
  5. Aromatic Products
    I. Indol
    J. Phenol
    K. Cresol

III. *End Products.*
  (Further action of germs.)
  H_2O, CO_2, $HC_2H_3O_2$, NH_3, H_2S, Fatty substances.

IV. *Results of Action of Formocresol.*
  Formalin plus H_2S (hydrogen sulphid) = Urotropin.
  Formalin plus NH_3 (ammonia gas) = Methyl alcohol and sulphur.
  Formalin plus Ptomaines and other protein material = Inodorous, harmlesscompounds.
  Cresol plus fats = Antiseptic soaps.
  Formocresol plus germs = sterilization and death of germs. (The carbohydrate material is not considered.)

is burned out and the canals cleansed of their contents. Avoid forcing the preparation through the apex, on account of its caustic and irritating effects. In addition to saponification of the gangrenous pulp tissue and its detergent effect, bleaching of the tooth is accomplished. The preparation also, owing to its chemical effect on the walls of canals, is valuable in enlarging small canals. The operation is repeated when, in some instances, the canals may be filled at once. In other cases an anodyne antiseptic dressing, or hydrogen dioxid, may be sealed in position and the sodium dioxid treatment repeated at a subsequent visit, if found necessary. The use of sodium dioxid for treatment of putrescent pulps has rapidly diminished recently, on account of its caustic effects on the periapical tissues in uncomplicated cases.

"Open Treatments."—Open treatments are rarely indicated and have been largely abandoned, on account of the additional time required, their tendency to keep up the infection, to produce discoloration, and to dilute and neutralize the effects of the remedies employed, from the continued entrance of saliva. However, in cases where it is impossible to see the patient at short intervals for continuation of treatment, they will of necessity sometimes have to be used. The contents of the chamber and canals are mechanically and chemically removed with broaches and similar instruments and some of the therapeutic remedies being described, when the germicidal agents are placed in the tooth, sealed with gutta-percha, and the sealing agent then perforated to allow for escape of the putrefactive gases. The treatments are repeated at intervals until the case is deemed ready for filling.

Kalium-natrium (Sodium and Potassium Alloy). (Schrier).—This is a strongly caustic alloy, of a pasty consistence, of sodium and potassium supplied in small, sealed glass tubes. When brought in contact with moisture in the canals, oxidation of the metals occurs through union of O with the water. Nascent oxygen is thus liberated with the formation sometimes of a resultant flame. The preparation is carried into the canals on a broach and acts similarly to the sodium dioxid salt. It is strongly caustic, destroying animal matter and assisting in enlargement of the canals.

Silver Nitrate and Formalin. (Percy R. Howe).—A combination of the double salt of ammonium-silver and formalin has been advocated by Howe for the treatment of putrescent pulps and chronic alveolar abscesses. The author does not believe that this method should be used as a routine measure in the treatment of cases of this nature, owing to the marked tendency of the silver salt to produce discoloration of tooth structure. If forced through the apical foramen in uncomplicated cases of putrescent pulp, it is also strongly irritating.

The method of application, as advocated by Howe is as follows:

Under aseptic precautions, remove the contents of the pulp chamber and apply the silver nitrate solution (bottle number one), saturating the remaining pulp tissue in the canals. Then, after waiting about three minutes, apply the formalin (solution number two) and allow the mixture to remain in position three minutes, when the canals may be opened and their contents removed. Now apply on a smooth broach, or absorbent point, a drop of solution number one, manipulating the solution carefully with a smooth broach, avoiding forcing through the foramen. Then, after an interval of three minutes, carry in a drop of solution number two, and thoroughly broach out the canals. After an interval of another three minutes, dry the canals thoroughly and apply another drop of the silver-ammonia solution (number one), to which is then added a drop of eugenol, and the broaching process continued. After three minutes, dry the canals and fill.

In cases of chronic alveolo-dental abscess, the same method of treatment is applied to the canals and the routine treatment for apical abscess is then instituted. During the abscess treatments, Howe recommends sealing Dakin's solution into the canals during the intervals between the visits of the patient. After healing of the abscess, again make three or four applications of the silver-ammonium-formalin preparation in the canal, and then fill.

Solution of Dichloramin-T.—This preparation is still being advocated by some for the sterilization of root canals and infected apical tissues. Its principal disadvantages are its marked tendency to produce irritation and an excessive flow of lymph. For these reasons the author cannot recommend its use. However, a brief description of the technic of its manipulation is herewith given.

A 5% solution of the salt in chlorosane (chlorinated paraffin) is recommended by Herman Prinz. Dichloramin-T solutions deteriorate very rapidly, consequently, only fresh solutions should be used and these should be kept in glass-stoppered, amber-colored bottles, which protect them from the light. The solutions should be kept away from heat, light, and contaminating substances of all kinds. To prepare an ounce of the preparation, twenty-five grains of dichloramin-T are added to one ounce of chlorosane, the mixture thoroughly shaken, and the bottle placed in a pan of very hot water, when, at the end of fifteen minutes, complete solution usually results. A few drops of the preparation should be removed from the container with a glass rod and placed on a glass tray ready for use.

Now, after opening the pulp chamber and canals, and thoroughly drying under aseptic precautions, carry the solution into the canals on an absorbent point. Do not use broaches for this purpose, as metals produce contamination of the liquid. With a pumping motion thoroughly moisten the canals. The use of the warm air blast from a chip blower or hot air syringe helps further to diffuse the oily liquid into the finer ramifications of the canal. A fresh point carrying the dichloramin-T solution is now sealed in the canal for twenty-four hours, at the end of which time the treatment is repeated and the solution sealed into position for another twenty-four hours. A third application is made in the same manner on the return of the patient and left in position for forty-eight hours, at the end of which time the case is ready for filling, if all evidences of putrefaction have disappeared. Dichloramin-T, owing to the fact that it is an active lymphagogue, usually produces a marked serous discharge, which, it is claimed by the advocates of the method is an advantage, especially in cases of septic conditions at the root end, on account of the increased tendency to produce efficient drainage.

Other Methods of Sterilizing Pulp Canals and Periapical Tissues.—Aqueous solutions that liberate free chlorin seem to be becoming more prominent in the treatment of putrescent pulps. All of these agents depend on the liberation of chlorin gas, which has an affinity for hydrogen. As a result, hydrochloric acid is formed as a by product and free oxygen is liberated, which oxidizes the products of bacteria and bacterial decompositions. The formation of hydrochloric acid is probably the source of irritation in the use of Di-chloramin-T and other chlorin solutions. Chloramine-T, a water soluble salt, (sodium paratoluensulphonchloramid) is also used for the same purpose.

To reduce the tendency to its irritating effects, J. R. Blaney in the Journal of the American Dental Association, Vol. XV, No. 2, Feb. 1928, page 203, advocates an alkalinized solution containing paratoluensulphonchloramid (Chloramin-T), sodium hypochlorite and sodium chlorid. Agents of this nature—in fact, irritating caustics of all kinds should be confined to the root canals and not be forced out into the periapical tissues. This is done with the idea of destroying the bacterial infection within the canals and depending on the biologic forces of nature to eliminate infection in the apical space. If they do not do so, surgical interference, rather than dependence on drug applications is indicated.

Beechwood creosote; equal parts of creosote and 3% tincture of iodin; and eugenol are also effective non-irritant agents in root canal sterilization.

The formula of Grieves has previously been mentioned. The remedies used should be fresh and clear solutions, else they should be discarded, on account of the danger of staining the dentin and because the efficacy of their therapeutic effect is lowered or lost through contamination. Agents used in root canal work should possess (1) high antiseptic properties without irritant effects; (2) they should maintain their activity for at least twenty-four hours; (3) they should not cause pain; and (4) they should not produce discoloration.

Ionic Medication. (Ionization.)—During the past decade ionic medication of septic root canals and of infections of the periapical tissues has come into prominence. This method of treating conditions of this nature has been advocated by M. L. Rhein, Weston A. Price, George T. Fette, Herman Prinz, Ernest Sturridge, of England, and others. At the present time, it may be said that with improvements in ionization apparatus and technic the results obtained are satisfactory in many instances, especially when used subsequently to pulp removal, for sterilization of the canals, dentin and periapical tissues.

The process consists of dissociating the ions of certain salts in solution by means of a mild electric current, and thus driving them into the tooth structure and apical space. Several prominent forms of appliance for this purpose are on the market. These appliances usually consist of current regulators and indicators for controlling, regulating and indicating the strength of the current, a cheek electrode, to be placed on the cheek of the patient, a tooth electrode carrying a metallic point to be inserted into the canal to be treated, current and motor generators and transformers, to be used in connection with direct or alternating street currents, and other accessories. Fig. 891.

The chemical agents recommended for ionic medication by the previously mentioned authorities are zinc chlorid or sulphid, 3% solution; copper sulphate, 2% solution; silver nitrate, 3% solution; tincture of iodin and water, equal parts; Lugol solution and Churchill's iodin solution. Of these the zinc chlorid, Lugol, and Churchill solutions have proven most satisfactory and are the agents of choice. The canal to be treated is saturated with one or the other of these latter solutions, the small tooth electrode needle is placed as deeply as possible in the canal, the face electrode is applied to the cheek of the patient and the current is turned on and slowly increased in amount, thus dissociating the ions of the solution and driving them into the tissues to be sterilized. The strength of the current is increased to two or three milliamperes for anterior teeth, and about three to five milliamperes for molars. The treatment is applied from five, to ten, to twenty minutes duration, depending on the conditions present and the size of the teeth treated. If five milliamperes of current are used the time of application should be six minutes. If three milliamperes, ten minutes, etc. the constant being thirty in all cases. In periapical infections, treatments are made every other day until pus flow ceases, and then at intervals of three or four days for several additional visits of the patient, at the end of which time, if all evidences of septic infection have disappeared and healing has occurred, the canals are ready for filling. In its present state of

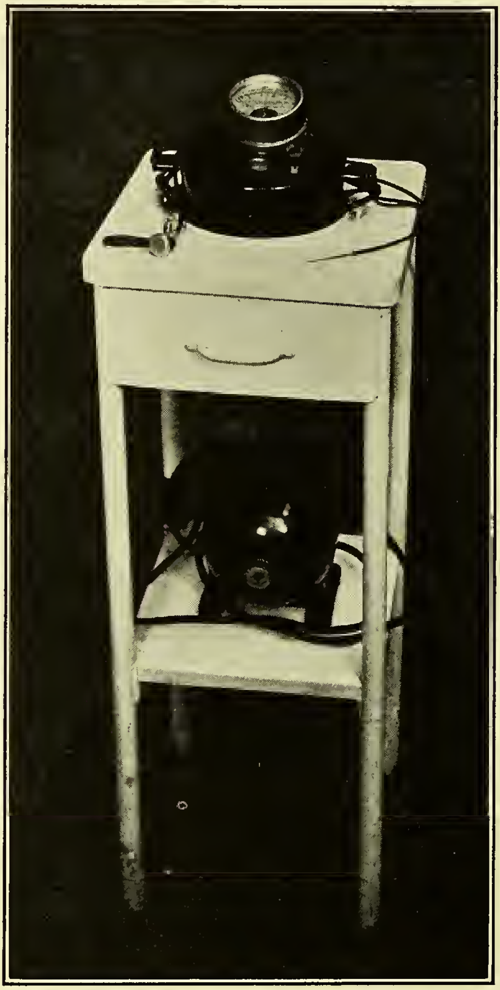


Fig. 891.—Ionization apparatus on stand, which may be conveniently rolled to the operating chair.

development, ionic medication cannot be depended upon for primary sterilization in the treatment of moist gangrene and periapical infections. Some of the chemical remedies mentioned should first be used in combination with the mechanical removal of the contents of the canals. On completion of the treatments, ionization may then be applied before filling the canals, with additional assurance of a successful termination. As a routine procedure following treatment and removal of vital and devital pulps, it has made a valuable place for itself.

DISEASES OF THE PERIDENTAL MEMBRANE AND PERIAPICAL TISSUES

Classification.—Diseases of the pericementum may be classified from several standpoints. Three classifications are herewith offered:

First.—Septic and non-septic (classification according to cause).

Second.—Acute and chronic (time classification).

Third.—Localized and general (classification according to extent).

Fourth.—Black's classification (classification according to locality), viz.,

A. Diseases of the pericementum beginning at the apex.

B. Diseases of the pericementum beginning at the gingival margin.

C. Diseases of the pericementum beginning at some intermediate portion of the root.

General Considerations.—The pericementum possesses a number of important functions, among which may be mentioned the following:

First.—It is the formative structure for the cementum.

Second.—It is the organ of nourishment for the cementum.

Third.—It acts as a ligament, binding the tooth in its socket.

Fourth.—It is the tactile organ for the tooth.

Fifth.—It acts as a cushion against the stresses of mastication.

The pericementum becomes thinner with age, while the cementum has a tendency to become thicker, through the formation of successive laminae of cemental depositions. Since it is one of the terminal parts of the body, and far removed from the heart, the pumping organ, it is especially subject to degenerative tendencies. Owing to its large blood and lymphatic supply, it is also notably subject to inflammatory disturbances, which are quite likely to lead to suppurative conditions in the presence of infection. Diseases of this membrane readily spread to the overlying gingival tissues, and *vice versa*, owing to their collateral circulatory connections. Inflammatory disturbances of the pericementum often cause a thickening of the membrane and a weakening of the attachment of the tooth, resulting in protrusion and looseness.

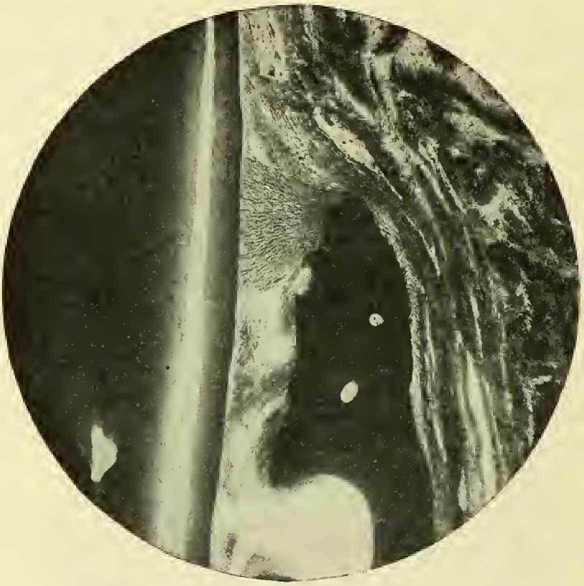


FIG. 892.—Alveolar crest group of principal fibres of pericementum, showing their insertion into cementum (shown on left), and alveolar crest (dark area in center). (Courtesy of Dr. Harold K. Box.)

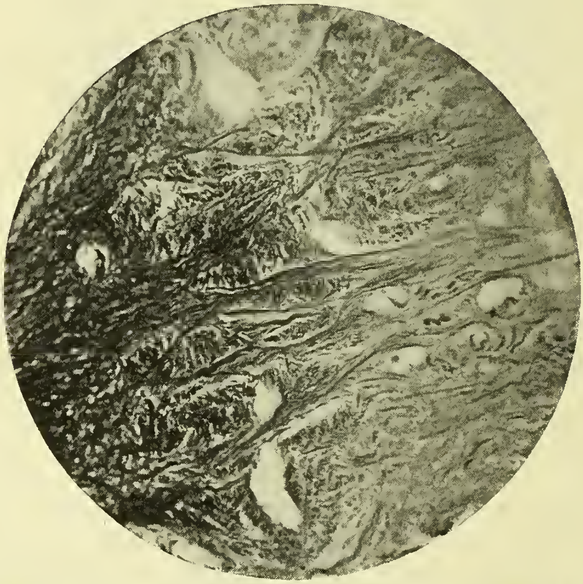


FIG. 893.—Trans-septal group of principal fibres of pericementum passing through cemental gingiva. (Courtesy of Dr. Harold K. Box.)

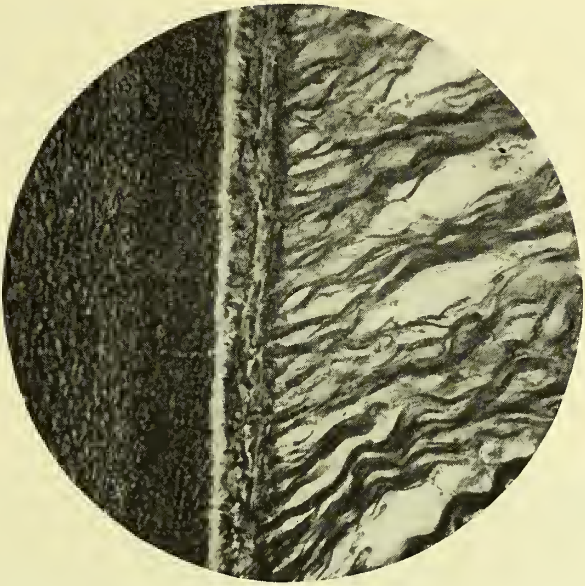


FIG 894.—Oblique group of principal fibres of pericementum. Cementum seen in center. (Courtesy of Dr. Harold K. Box.)

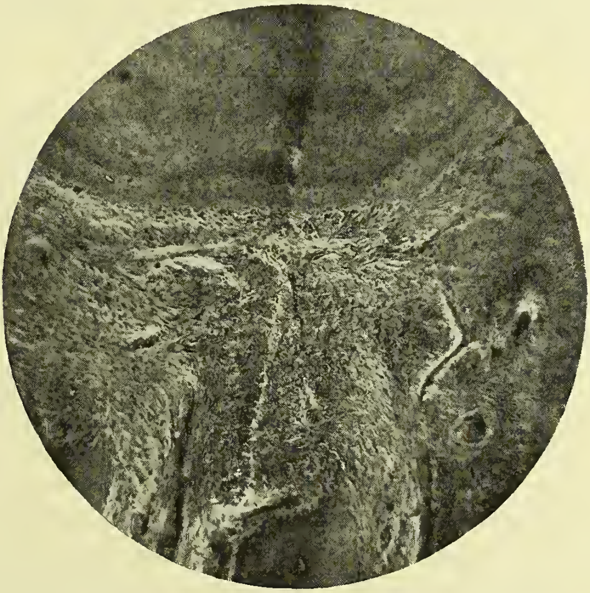


FIG. 895.—Apical group of principal fibres of pericementum. Apical cementum above alveolar bone in center of lower edge. (Courtesy of Dr. Harold K. Box.)

As has been mentioned previously, the pulp has no sense of location, because of its lack of tactile nerve endings. The pericementum, since it is richly endowed with terminal nerve endings of this type, acts as the touch organ, with the result that pressure on the tooth is immediately transmitted in this way and thus definitely located. Figs. 892 to 895.

Differential Diagnosis.—A general differential diagnosis between affections of the pericementum and pulp disturbances is herewith offered:

Diseases of the pulp are characterized by:

First.—Response to thermal stimuli.

Second.—Reflected pains.

Third.—No tenderness on percussion, unless the pericementum be involved.

Diseases of the pericementum are characterized by:

First.—Localized pains.

Second.—Tenderness on percussion.

Third.—A dull percussion note when tapped with an instrument, due to thickening of the membrane.

Fourth.—Protrusion and looseness of the teeth.

Fifth.—Deepening of the overlying gum color.

Sixth.—No response to thermal stimuli, per se.

NON-SEPTIC PERICEMENTITIS

Synonyms.—Traumatic pericementitis, ordinary pericementitis, non-suppurative pericementoclasia.

Causes of Non-septic Pericementitis.—The causes are largely of a non-spetic nature, although septic conditions also may be concerned. However, cases due to septic causes, if continued, will naturally be likely to be transformed at any time into a septic pericementitis. The causes may be mentioned as follows:

1. *Drug Irritants.*—Cocain, novocain, arsenic, caustic alkalies, strong acids and escharotics, when carried through the apical foramen; also mercury and other systemic poisons, when taken internally, the pericementum being especially susceptible to the irritating effects of mercury and other metallic poisons. Certain constitutional states, such as grip, common colds, menstruation, etc. previously mentioned as concerned in pulp disturbance, are also productive of this condition.

2. *Mechanical Irritants.*—Imperfect canal fillings, protruding or otherwise; passage of instruments through the apex; protruding broken

broaches; ill-fitting partial plates, crowns, and bridges; excessive malleting of fillings; injudicious regulating of the teeth; faulty occlusion from overfull fillings and crowns, or any other cause; lack of occlusion from improperly-restored occlusal restorations or loss of antagonists; accumulations of calculus; blows on the teeth; habits, such as nut cracking and thread biting. Figs. 896 to 903.

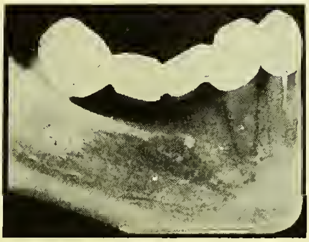


FIG. 896.—Poor root filling, first bicuspid. Absorption of apex, second bicuspid.

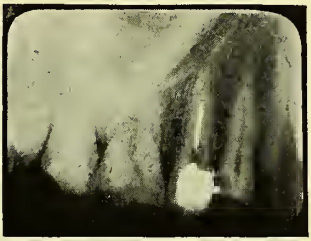


FIG. 897.—Poor canal filling with broken broach.

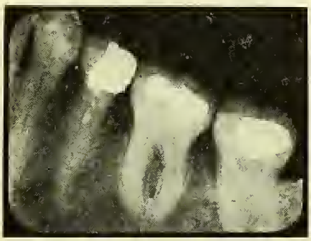


FIG. 898.—Poor root canal therapy in bicuspid.

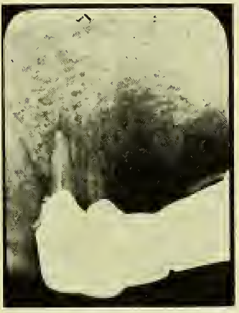


FIG. 899.—Faulty canal filling, recent extractions.

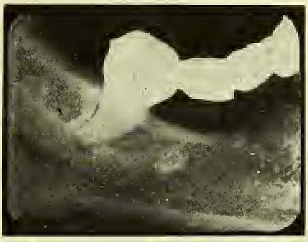


FIG. 900.—Thickening of peridental membrane, third molar. Condensed bone, second molar region.

Pericementitis from cocain, novocain and arsenic may be due to true drug action or to improper methods in handling. Phenol, volatile oils, sodium dioxid, sodium-potassium alloy, sulfuric acid, zinc chlorid, and similar agents, carelessly handled in a root canal, may produce marked irritation of the tissues of the apical space. The forcing of air or root fillings into the tissues, the careless wounding of the parts, by the passage of broaches through the apical foramen, imperfect filling of the apical third of the canal, the sealing of treatments with temporary stopping on occlusal surfaces, these acting as an elastic cushion, are all frequent additional causes.

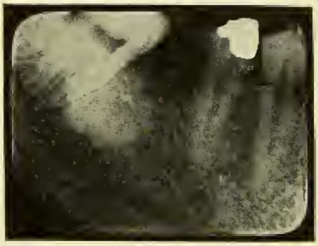


Fig. 901.—Condensing bone mesial to second molar, due to drifting.

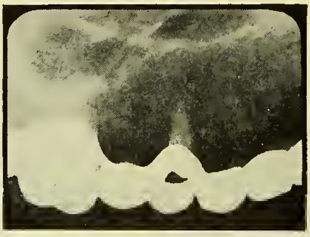


Fig. 902.—Pericementitis around bicuspid root. Crown worn through. Trauma.

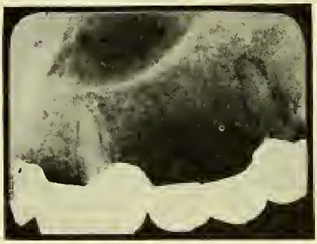


Fig. 903.—Marked pericementitis around lateral, probably due to trauma. Condensed bone around second bicuspid from same cause.

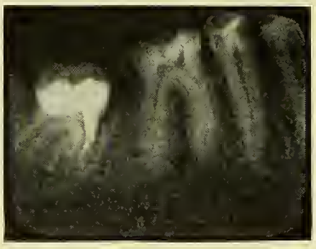


Fig. 904.—Hypercementosis. Caries on mesial and distal of second bicuspid and distal of first molar.

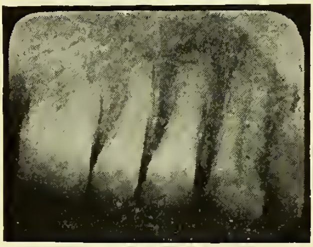


Fig. 905.—Hypercementosis.

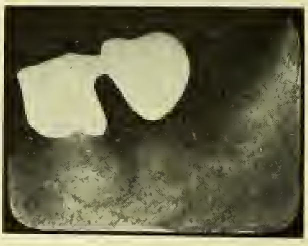


Fig. 906.—Hypercementosis.

Symptoms and Diagnosis.—The condition may be located in the tissues of the apical space or on some lateral aspect of the root, depending on the nature of the cause. Tenderness on pressure, protrusion of the tooth, looseness and deepened gum color are frequent. If from drugs used in canal work, these symptoms usually are temporary, though occasionally this is not so, especially if due to arsenic or pressure anesthesia. Malocclusion may be detected by occlusion marks on fillings, or by carbon paper. A history of the case is valuable in making a diagnosis. The radiograph is of assistance in detecting protruding root fillings and similar conditions. Over-use, misuse, or disuse of the teeth, as well as other causes long continued are likely to result finally in degeneration and loss of tone in the affected pericementum. Mild cases of non-septic pericementitis, long continued, occasionally lead to hypercementosis, or to resorptions of the root. Figs. 904, 905 and 906.

Treatment of Non-septic Pericementitis. *First, Remove the Cause.*—A correct diagnosis is important. A root filling usually should not be removed if the operator is sure it is perfectly placed. Relieve excessive occlusion by grinding, or supplying missing teeth. Remove ill-fitting crowns, bridges and dentures and supply properly-fitting appliances.

Second, physiological rest often is indicated. Instruct the patient temporarily to avoid chewing on the affected tooth, or where indicated, ligate the affected tooth to its neighbors, or swage a metallic splint and fit it over the adjoining teeth, to relieve the stress.

Third, Relieve Pain.—If the canal is open or has been opened, sedative non-irritating applications may be used in it, such as clove oil, eugenol, thymol in alcohol, phenol compound or thymophen. Volatilization of clove oil by means of heat from the chip blower or hot air syringe through the canal into the apical tissues, occasionally will prove serviceable.

Fourth, counterirritation of the overlying gingival tissues with tincture of iodin, tincture of aconite, capsicum plasters and similar means is frequently of value.

Fifth, general systemic remedies, such as pediluvia, salines, and similar derivative measures often are valuable. Internal administration of sedatives and bromides will be of service.

ACUTE ALVEOLO-DENTAL ABSCESS

Synonyms.—Acute alveolar abscess; acute apical abscess; acute, septic, apical pericementitis; dento-alveolar abscess; acute periodontal abscess.

Causes and Pathology.—The causes of this condition are the entrance of pus-forming germs and the escape of the gases and intermediate products from a putrescent pulp into the tissues of the apical space. Lack of aseptic precautions in treating canals, and imperfectly treated and filled canals also are frequent causative agents. An abscess on an adjoining tooth, or infection from a pyorrhea pocket, also may extend by way of the circulation, or by continuity of tissue, and produce the condition.

The infective organisms found in root end infections are of various types. Hartzell and Henrici made a number of reports as to their findings in the Journal of the American Dental Association during 1913, 1914, and 1915. They found the streptococcos viridans constantly present, of which groups S. salivarius and S. mitis predominated. In addition to these, they discovered the presence of Staphylococcus albus, Bacillus coli, B. fluorescens and the Pneumococcus. Other investigators have found Staphylococcus aureus and citreus, Micrococcus catarrhalis and Bacillus fusiformis.

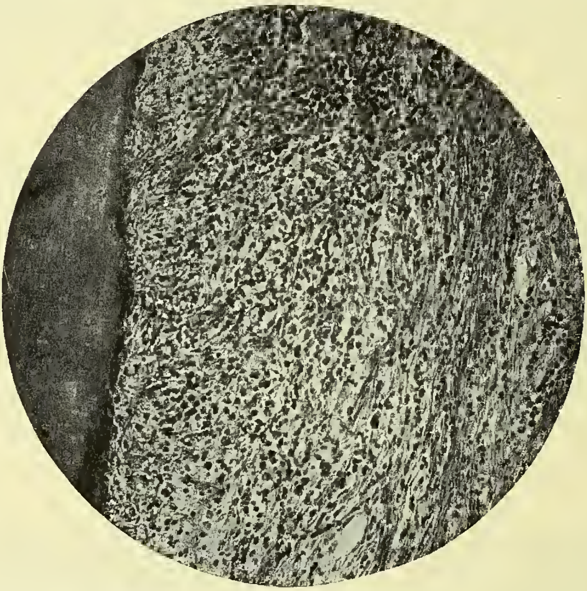


FIG. 907.—Acute alveolar abscess showing polymorpho-nuclear infiltration in early stage Cementum shown to the left. (Courtesy of Dr. Harold K. Box.)

As a result of infection, the periapical tissues become subject, first, to arterial hyperaemia, leading into venous hyperaemia and later inflammation of an acute type. Following the inflammatory stage, the tissues of the apical space are broken down and liquefied into pus, through the action of the suppurative and putrefactive germs present. This constitutes the *first or initial stage.* Fig. 907. In the *second or perforative stage* the increasing pus formation takes the line of least resistance, and bores its way, in the majority of cases, through the alveolar plate of bone on the labial or buccal aspect of the affected root and into the overlying soft tissues. In the *third stage* the advancing pus perforates the soft tissues, making an opening usually about one-third of an inch below and slightly to the distal side of the apex of the affected root. In this stage, swelling of the soft tissues usually is marked.

In other cases, however, the pus, taking easier avenues of escape, will open on the lingual side, in the roof of the mouth, into the nasal cavity, the antrum, the inferior dental canal, the fauces, on the cheek, below the chin, beneath the angle of the jaw, or at far-distant points. (Figs. 908 and 909.) In cases of open cavities, the pus may find exit by way of the canals.

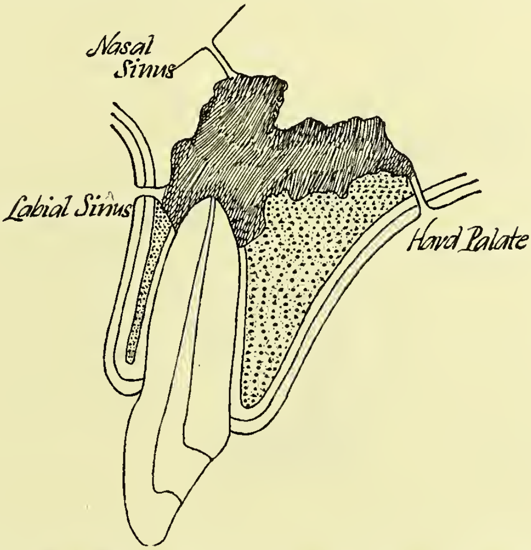


FIG. 908.—Sketch showing avenues of exit for pus in alveolar abscess on anterior teeth.

During the progress of the disease, the bone and overlying structures are being broken down constantly, liquefied and transformed into pus. After perforation has occurred, the condition remains, if untreated, as a chronic abscess cavity at the root end, with a sinus leading from it to a fistulous opening at the point of exit. If perforation does not occur, as occasionally happens, and the case does not receive treatment, a chronic abscess without fistula is established, the pus draining through the canals or being absorbed into the vascular and lymphatic streams.

Symptoms.—The symptoms are both local and constitutional.

Local Symptoms.—In the early part of the first stage there may be reflex pains, with slight tenderness on pressure, the latter symptoms being occasionally relieved by forcible and prolonged antagonism of the opposing teeth. Later, however, with the increase of the inflammatory disturbance, the pain becomes definitely localized, while during the second or perforative stage it reaches a climax of intensity, with deepening of the local gum color, excessive tenderness on the slightest touch, and protrusion and looseness of the affected tooth. The adjoining teeth also become very tender to pressure or percussion. In the third stage, there may be extensive swelling of the soft tissues, with increased protrusion and looseness, extension of the inflammatory area, with great swelling of the cheek or neck, involvement of the eye and cervical glands on the affected side, (lymphadenitis), and other evidences of the progress of the infection toward the surface. Finally, pointing of the abscess occurs and, since pressure is now relieved, the acute symptoms largely subside. A sudden subsidence of the pains and other acute symptoms, in the absence of visible pointing, would indicate the possibility of pointing into some of the internal cavities previously mentioned, or into some obscure locality. In cases of open cavities, with drainage through the canals, the symptoms may not be so marked.

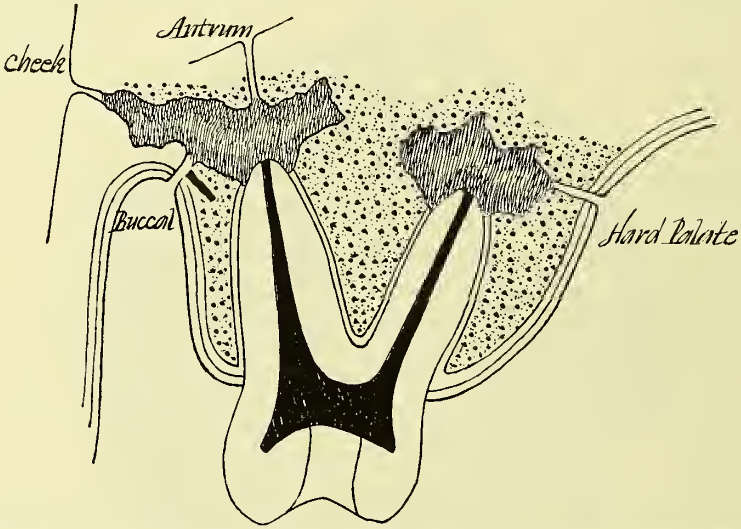


FIG. 909.—Sketch showing some of the avenues of exit for pus on posterior teeth.

Constitutional Symptoms.—Constitutional symptoms always are present, but are more marked in the more diffuse forms with streptococcus infection. The usual systemic manifestations are fever, chills, full, hard, rapid pulse, coated tongue, constipation, weakness, irritability, anorexia, and sleeplessness. In the graver forms, especially in the diffuse variety, evidences of septicemia, from great absorption of toxic products into the blood and lymphatics, may occur in the form of soft, frequent pulse, repeated chills, diarrhoea, cold, clammy skin, great depression, disorders of the nervous system, and even death.

General Outline of the Treatment.—The treatment in the main is Abortive in character, to prevent the spread of the infection and the continued formation of pus. The measures applied are both local and general or systemic in character.

Local Treatment.—Under aseptic precautions, open into the pulp chamber, either through a cavity, old filling, or the lingual, or occlusal surface of undecayed teeth. As soreness usually is present, pressure may be somewhat relieved during the necessary drilling by traction on a ligature tied around the affected tooth, or the use of a modeling-compound splint held in position over several adjoining teeth. The rubber dam should, as a rule, not be applied at the first sitting, owing to the excessive soreness of the tooth. Broach out the canals as well as conditions will admit, to relieve the pressure of the confined gases and allow drainage for pus formation. Flush out with an antiseptic solution, absorb pus from the canals on cotton or paper points, and either (a), pump in an anodyne antiseptic, such as phenol compound, creosote, creosote and 3% tincture of iodine equal parts or one of the aforementioned preparations liberating chlorine, leaving the tooth open to allow for drainage, repeating the treatment at intervals of a few hours until relief is secured; or (b) seal in for a few hours, to be repeated at increasingly longer intervals, formocresol, as in an ordinary treatment for putrescent pulp. In either case, counterirritation to the gingival tissues, scarification in the early stages; or, in the later stages, free lancing of the gum, drilling through the bone to the apex of the affected tooth with a spear-point drill or trephine, and the use of a tent for drainage frequently are indicated.

As counterirritants one of the following remedies may be applied, viz.: Tincture of iodin and aconite, equal parts, capsicum plasters, black mustard papers cut to proper size, or one of the following prescriptions:

℞. Mentholis	gr. XX (1.25 gm.)
Chloroformi	ʒ I (4.00 cc.)
Tincturae Aconiti, q.s., ad	℥ I (32.00 cc.) (Buckley)

℞. Tincturae Aconiti	ʒ II (8.0 cc.)
Tincturae Iodi,	
Chloroformi	aa ʒ I (4.0 cc.) (Buckley)

In some cases, in the later stages, where other methods fail, heat may be applied to the gum in the form of hot water, a split raisin sprinkled with capsicum, a capsicum plaster, or Poloris, to hasten suppuration and pointing. Antiseptic mouth washes should be used freely. Cold applications to the cheek to decrease swelling and tendency to external pointing will be serviceable. Never apply heat or external poultices for this purpose.

Systemic Treatment.

1. *Administer iodides* to aid nature in readjusting the parts to a normal condition.

℞. Potassii iodidi	ʒ Iss (6.0 gm.)
Syrupi sarsaparillae compositae	℥ III (96.0 cc.)

Sig. Teaspoonful every two hours until three or four doses have been taken, then three times a day.

2. *Saline cathartics*, such as Epsom salts, seidlitz powders, or citrate of magnesia, to lower the force of the circulation, withdraw blood from the affected area, and enable the system to throw off the toxins being absorbed into the circulation, are useful.

3. *Relieve pain and reduce fever* by the use of ipral aminopyrine, pyramidon, acetanilid, phenacetin, or, as a last resort, opium or its derivatives.

℞. Pluveris acetanilidi compositi	gr. XX (1.25 gm.)
Ft. Capsulae No. 3	

Sig. Take one every two hours.

4. *A hot mustard foot bath* to draw the blood away from the affected area to the lower extremities is of value.

The prognosis of acute alveolar abscess usually is good, as far as preservation of the tooth is concerned, especially if treatment be applied early. In cases of extreme boggy swelling, great involvement of the tissues of the face, and evidences of marked septicemic infection, extraction is sometimes the only alternative. In these cases it is frequently a matter of nice judgement to determine whether to extract at once or to use measures to hasten suppuration and pointing, deferring the operation, rather than run the risk of stimulating an increase of the cellulitis, periostitis, constitutional manifestations and systemic infection, as a result of the operation. In many instances, however, where the indications point to a very grave termination, due to marked septicemia, it will be the part of widsom to extract immediately under aseptic precautions and stimulative treatment. Thrombosis of the cavernous sinus is always a grave possibility. Treatment and further discussion of cases of this nature lies within the realm of oral surgery. For further information, the student is referred to text-books on these subjects.

CHRONIC ALVEOLO-DENTAL ABSCESS

Synonyms.—Chronic alveolar abscess; chronic apical abscess; chronic, septic, apical pericementitis; chronic periodontal abscess; chronic periapical abscess.

Causes.—The causes are the same as those producing the acute variety. The condition is one in which pus formation is fully established, the tissues of the pulp are largely broken up, and the apical tissue has been destroyed to a point where an abscess cavity is present in that locality, while the acute symptoms of pain, tenderness and swelling have largely subsided. (Figs. 910 to 920 inclusive.)

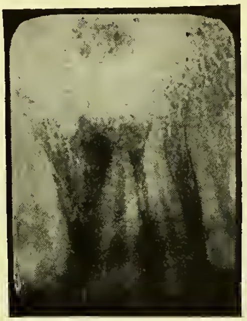


Fig. 910.—Chronic alveolar abscess.

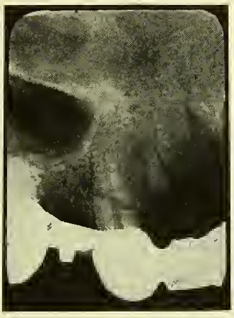


Fig. 911.—Retained lateral root with apical absorption under bridge.

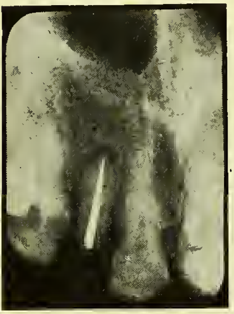


Fig. 912.—Canal filling and apical absorption on lateral. Fractured root on central.

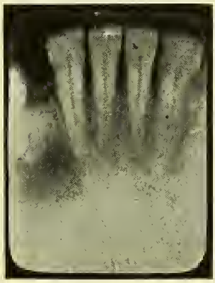


Fig. 913.—Embedded abscessed root.

The Varieties of chronic alveolar abscess are:

(1) *Abscess without sinus;* the pus discharging via the root canal (false blind abscess), or being absorbed via the lymphatics and the blood

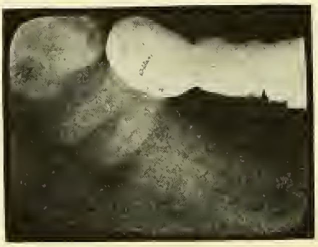


FIG. 914.—Chronic alveolar abscess and dwarf third molar.

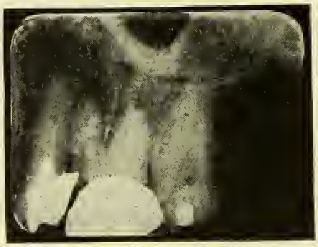


FIG. 915.—Chronic alveolar abscess and root absorption on first molar.

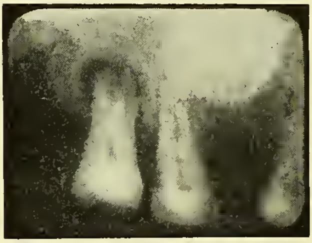


FIG. 916.—Alveolar absorption. Abscessed molar.

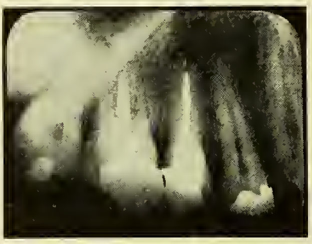


FIG. 917.—Chronic alveolar abscess, second bicuspid. Unerupted third molar. Imperfect canal fillings, first molar.

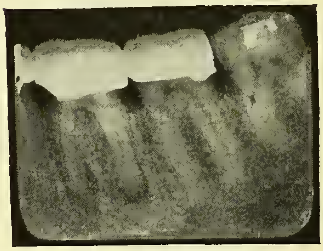


FIG. 918.—Chronic abscess on first molar. Poorly fitting crowns.

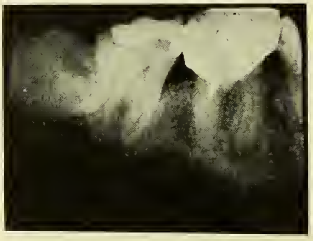


FIG. 919.—Abscess and poor root therapy, first molar. Impacted third molar. Absorption of interdental septa due to ill fitting crown.

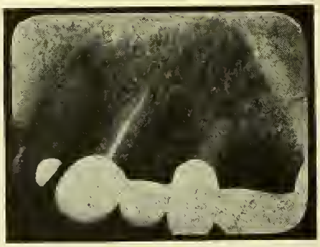


FIG. 920.—Chronic alveolar abscesses. Retained root under bridge.

streams (true blind abscess); and (2) *abscess with sinus;* the pus having bored its way through the overlying bone and opening externally.

Dangerous systemic conditions may arise from masked cases of chronic abscess without sinus in cases of lowered vitality. Local foci of infection may be established, in which the pus and toxic products are slowly absorbed via the lymphatics and blood streams, producing general depression of the metabolic functions of the system, and resulting in lowered vitality, infections in other parts, loss of vigor, sleeplessness, anorexia, anaemia, leukaemia, intestinal disturbances, rheumatism arthritis, and vague disturbances of internal organs.

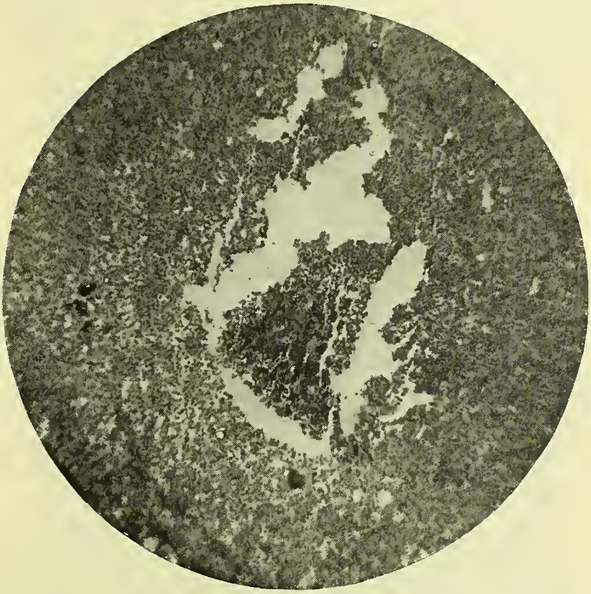


FIG. 921.—Chronic alveolar abscess surrounded by granulation tissue. (Courtesy of Dr. Harold K. Box.)

In chronic abscess with sinus, the acute symptoms, local and systemic, usually subside and the case may remain, if untreated, for long periods without any great discomfort to the patient. There is always danger of a "flare up" and return of the acute symptoms in chronic abscess where the exit to pus flow is closed through the formation of granulation tissues in and over the sinus, or the packing of food debris into open cavities. A silver probe is valuable for diagnosis of the length, direction and patency of sinuses. Figs. 921 and 922.

Treatment.—The routine treatment for chronic alveolar abscess is similar to the local treatment described for the acute cases, using in the canals one or the other of the remedies previously mentioned. Open the chamber and canals under aseptic precautions, remove the contents, evacuate the pus by pressure over the apex of the tooth and swabbing of the canals. Dry the chamber and canals and seal in formocresol, full strength, diluted, or modified, some of the chlorine preparations, or other antiseptics. A weak solution of chlorinated soda or lime is often good. Repeat the treatment frequently, sometimes daily, until the pus-flow stops; then seal in a mild, antiseptic, anodyne treatment, such as eugenol, eucalyptol or thymol in alcohol for a week or ten days; then, if the case is healed, as evidenced by stoppage of discharge, disappearance of all odor, tenderness and other symptoms, the canals may be filled, after being ionized. Over-treatment, or too frequent treatment, sometimes will result in the prolonged continuance of a serumal discharge, which is not pus. In these cases, dilute the remedy used or use eucalyptol compound (Buckley). If, after using one or the other of these remedies, serum continues to exude and microscopic examination of a smear shows absence of germs, dry and fill the canals, and give the case physiological rest for a week or two, before placing the permanent filling in the crown of the tooth.

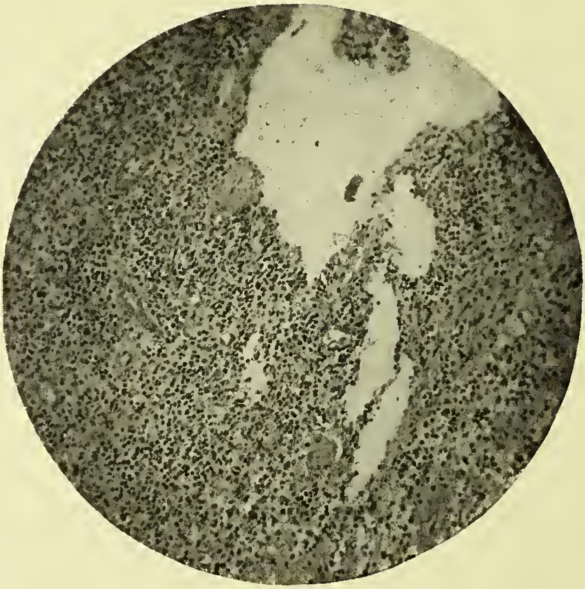


FIG. 922.—Chronic alveolar abscess surrounded by granulation tissue. (Courtesy of Dr Harold K. Box.)

Usually, no attempt should be made to carry medicinal agents through the apical foramen in these cases. They are likely to prolong the treat-

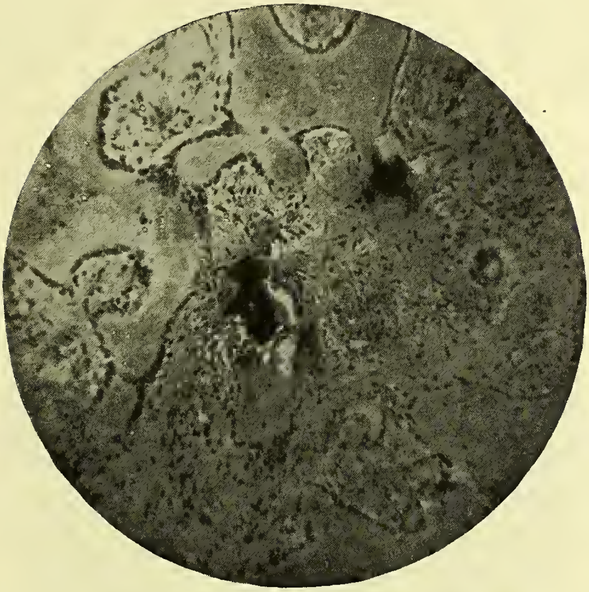


FIG. 923.—Rarefying osteitis. The dark areas represent osteoblasts. (Courtesy of Dr Harold K. Box.)

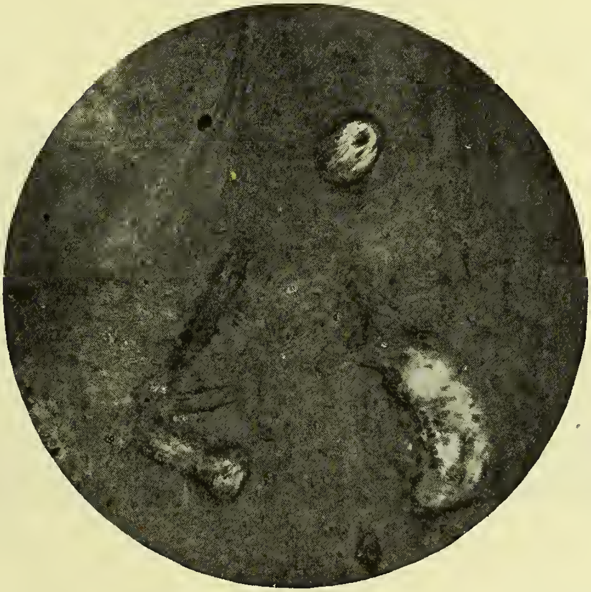


FIG. 924.—Condensing osteitis. (Courtesy of Dr. Harold K. Box.)

ment, traumatize, lower the resistance and produce further destruction of periapical tissue, which should be avoided. No treatment forced through the canal will be curative. Dependence should be placed in removal of the cause, through proper root therapy, and on the ability of the natural phagocytic and chemotactic forces of the body to restore the periapical tissues to a healthy condition. In patients of low recuperative

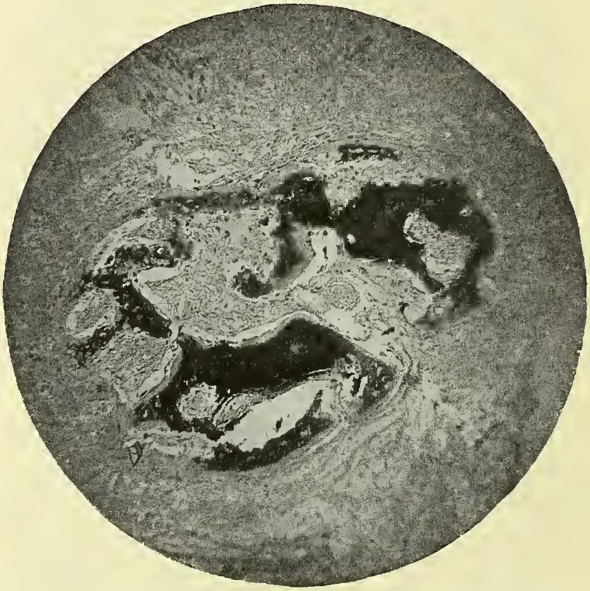


FIG. 925.—Remnants of bone (dark areas) surrounded by granulation tissue and undergoing absorption. (Courtesy of Dr. Harold K. Box.)

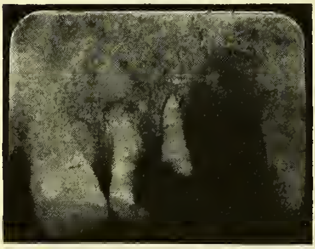


FIG. 926.—Condensation of bone at apex of badly infected tooth.

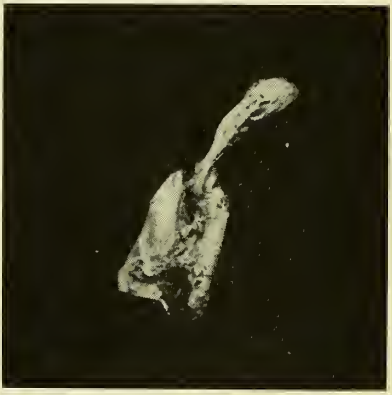


FIG. 927.—"Pus sac" at end of roots.

powers, or those particularly subject to purulent infections, the tooth will frequently have to be extracted, or the operation of apicoectomy (excision of the root end) performed. In chronic periapical diseases with fistula, the fistula may sometimes persist, unless it is removed by caustics and curettage.

In long continued chronic abscesses, *cementoclastic resorption* of the root end, together with destruction of the pericementum, liquefaction necrosis of surrounding bone, and deposits of *pyogenic calculus* may occur. In the milder forms of chronic periapical infections, the cementoblasts may produce *hypercementosis* on the apex of the root. In other instances, thin connective tissue capsules containing pus, form and attach themselves to the root apex. The arrangement of the connective tissue bundles in the capsule is similar to that seen in granuloma. They often come away with the tooth on extraction and present the appearance of small, soft, red or yellow swellings, the well known "pus sac." Sometimes they will remain in the root socket after extraction of the tooth and be the source of continued irritation and infection. These cases call for apicoectomy and curettage or extraction of the tooth, depending on the systemic condition and vital resistive powers of the patient, the value of the tooth as a part of the masticating machine and the ability of the operator to cope with the difficulties involved. In other cases of high tissue resistance, the purulent types of micro-organisms may be destroyed through phagocytosis and the case be transformed into a low grade, non-purulent type of infection. Figs. 923 to 927.

NON-PURULENT PERIAPICAL INFECTIONS

Low grade, non-purulent forms of infection produce pathologic reactions of a type which is quite different from those of the purulent types. In the latter there is usually rapid breaking down and destruction of alveolar bone, as already described. The non-purulent type is accompanied by a low grade inflammatory process, which is characterized by a localized infiltration of mononuclear leukocytes and a proliferation of fibrous tissue, which invades the areolar spaces and supplants the trabeculae of bone. These non-purulent, but infective processes are pathologically of two distinct types, viz.: (1) a localized necrosis of bone by which the bony trabeculae undergo a metaplastic change to fibrous tissue; or (2) a somewhat similar bone degeneration, accompanied by pronounced proliferation of fibrous tissue, resulting in the formation of a granuloma. In the first type mentioned, the bone frequently undergoes degenerative changes of a diffuse nature,

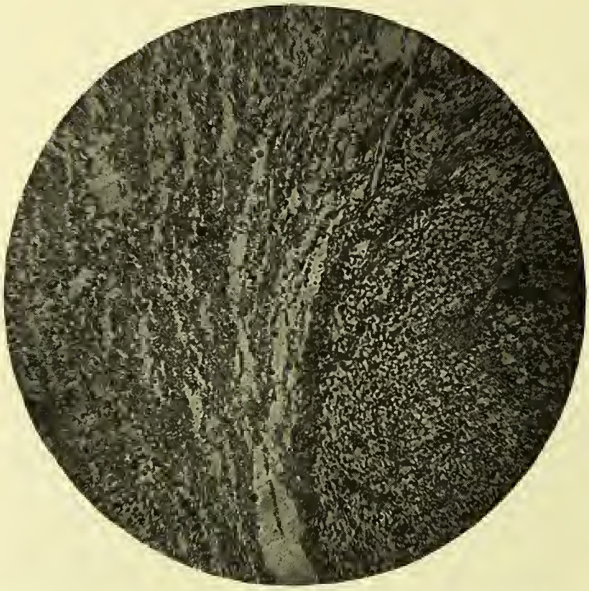


FIG. 928.—Simple granuloma with connective tissue capsule. Granulation tissue on right; connective tissue capsule to the right of center. (Courtesy of Dr. Harold K. Box.)

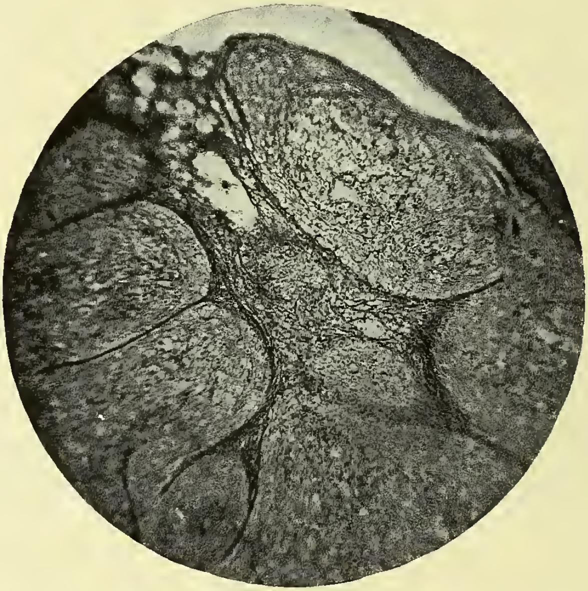


FIG. 929.—Cystic granuloma. Epithelial strands growing into the surrounding granulation tissue and tending to encircle it. (Courtesy of Dr. Harold K. Box.)

which are not definitely marked off from the surrounding normal tissue. This type of alveolar degeneration frequently presents no enveloping wall and the infective bacteria and toxins are consequently readily absorbed into the circulation, carried to distant parts and produce foci of infection in other tissues of the body. Figs. 928 and 929.

DENTAL GRANULOMA

For a full discussion of the dental granuloma and the dental cyst the reader is referred to the excellent texts on Dental Pathology of Moorehead and Dewey, Endelman, Prinz, and Bunting. The granuloma is, as already stated a bone degeneration, accompanied by pronounced proliferation of fibrous tissue and formation of a definite wall or sac, due to low grade, long continued, non-purulent infection from a root canal. The sac tends to enclose and definitely wall off the infection and prevent its absorption into the general circulation. This it does not entirely accomplish, however, and these dental root or radicular granulomata are often concerned in focal infections. Dental granulomata have been studied by Kurt H. Thoma, who reports several varieties in the Journal of the American Dental Association for October 1917, the characteristics of which are of primary interest to the histopathologist, but whose microscopic variations have no particular clinical significance.

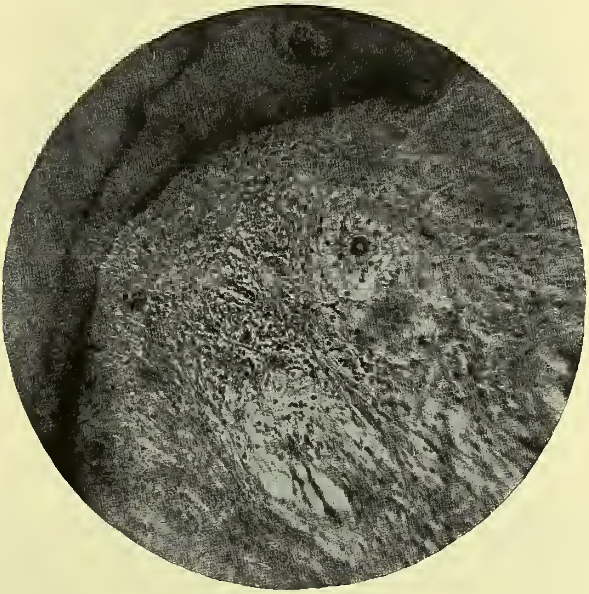


Fig. 930.—Granuloma forming between the bifurcation of the roots of a molar. Dentino-cemental junction above. (Courtesy of Dr. Harold K. Box.)

The accompanying illustrations of Dr. Harold Box indicate that the peridental granuloma may progressively increase in size, may be accompanied by fatty, calcareous and other degenerative changes, may be invaded by masses or strands of epithelial tissue or secondarily by purulent bacteria. The entrance of purulent microorganisms may transform the granuloma into a typical abscess. Thus it is seen that an apical abscess may be transformed into a granuloma, or *vice versa*, depending on a change in the type of germs present. Figs. 930 and 931.

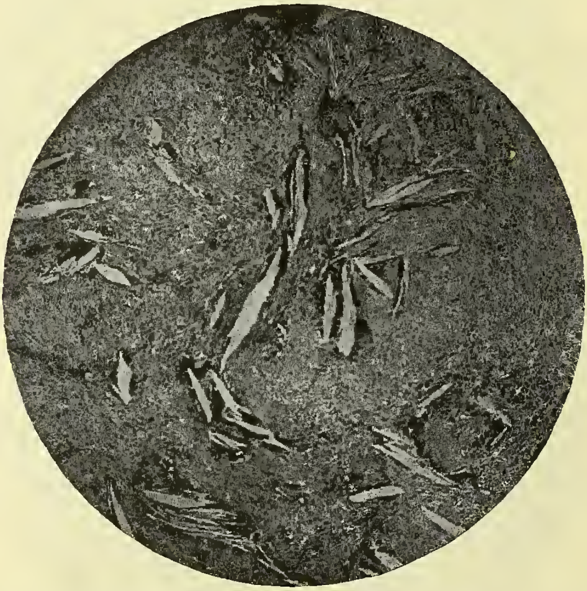


FIG. 931.—Granuloma showing cholesterin formation. (Courtesy of Dr. Harold K. Box.)

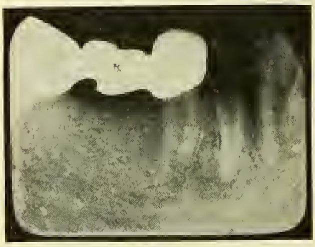


FIG. 932.—Granuloma.

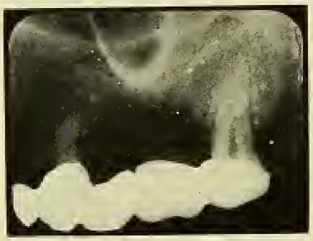


FIG. 933.—Granuloma on second bicuspid. Small amount of alveolar absorption on third molar.

Granulomata seldom, if ever, undergo spontaneous resolution. The capsule must be eradicated by surgical interference, either through apicoectomy and curettage or extraction and subsequent curettage.

If allowed to remain, these *residual areas of infection* are of great danger to the patient. Figs. 932, 933 and 934.

PERIAPICAL CYSTS

The epithelial type of granuloma may be accompanied by necrotic changes in its medullary portion with the formation of a cystic central cavity filled with fluid. The fluid content of a dental cyst is usually thin, turbid, and may contain fatty substances, cholesterin crystals and the remains of degenerated cells. The cavity is surrounded by a thin membrane of squamous epithelial cells and fibrous tissue, enclosed often in a condensed layer of bony tissue. Figs. 935 and 936.

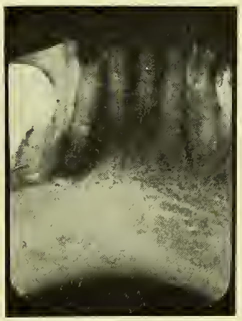


Fig. 934 —Large granuloma on lateral incisor.

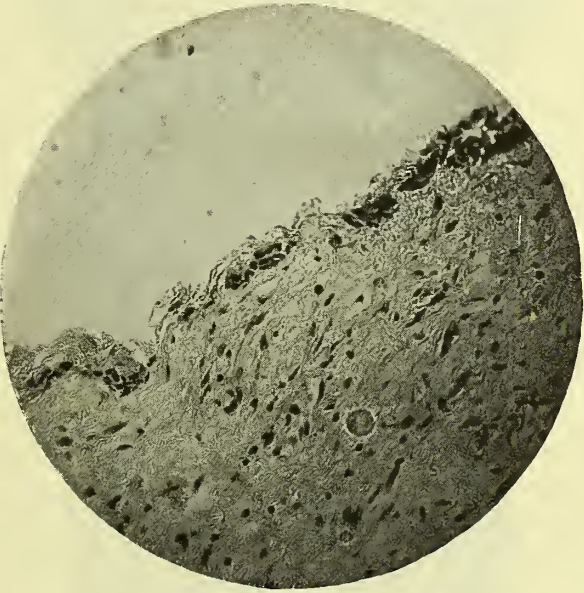


Fig. 935.—Root cyst. Cystic cavity above, epithelial lining of cyst in center, fibrous connective tissue capsule below. (Courtesy of Dr. Harold K. Box.)

SYMPTOMS AND DIAGNOSIS OF DENTAL GRANULOMATA AND CYSTS

The subjective symptoms may be entirely absent. Frequently there is no pain, although there may be an undefined feeling of discomfort, soreness, or tenderness. The presence of pulpless teeth may, together with these characteristic symptoms lead to roentgenographic examination. This may reveal areas at the root apex of varying size and

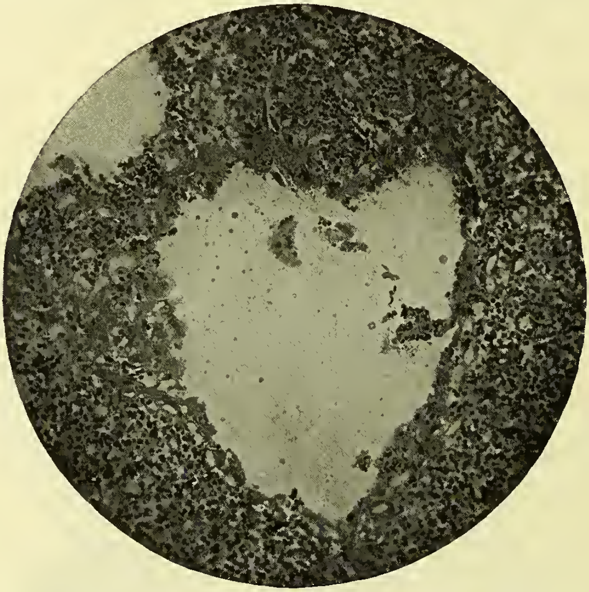


FIG. 936.—Root cyst surrounded by granulation tissue. (Courtesy of Dr. Harold K. Box.)

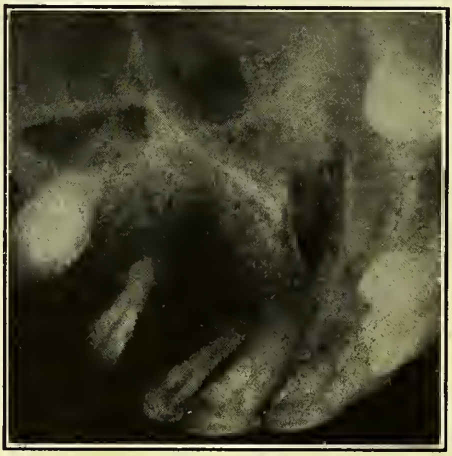


FIG. 937.—Cyst.

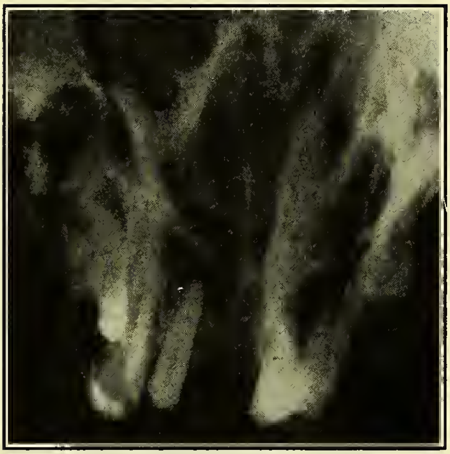


FIG. 938.—Cysts.

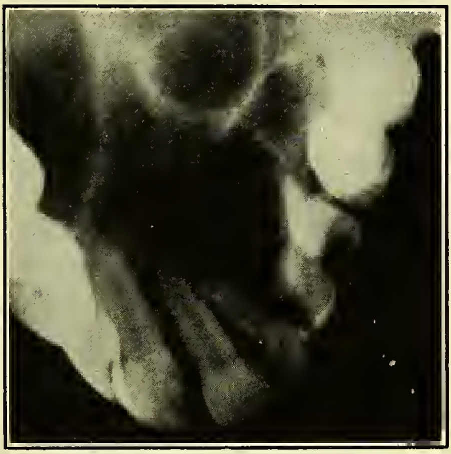


FIG. 939.—Cyst.

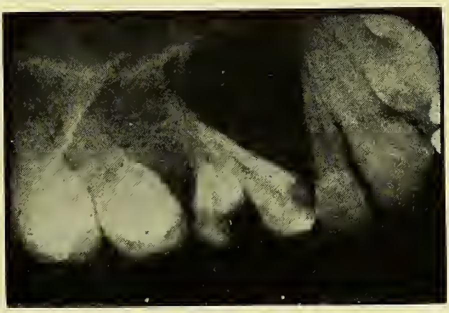


FIG. 940.—Cyst

appearance, depending on the nature of the pathologic disturbance. These lesions may be very small, or, if cyst formation is present, be quite large. The capsulated types of granuloma frequently have a different appearance in the roentgenogram than the diffuse forms of alveolar degeneration. A dental cyst may often be recognized by the regularity of its sharply defined borders. Figs. 937 to 940.

Treatment.—The treatment of all non-purulent types of periapical infections, including unwalled cavities, granulomata and cysts consists in surgical intervention, including apicoectomy or extraction and curettment.

When apicoectomy (excision of the root apex and curettage) have been decided upon, it will be better to refer the case to specialists in root therapy or oral surgery, who have developed the necessary skill through experience, to efficiently perform the operation. The general practitioner of dentistry usually has not had sufficient experience in this operation to produce the desired results. A brief description of the operation follows. Fuller and more detailed descriptions may be found in works on oral surgery.

APICOECTOMY

First fill the root canal, after having obtained a radiograph. Then inject a local anesthetic, and, under aseptic precautions, make a linear, or preferably a semi-circular incision of the gum over the apex, cutting to the bone. (Fig. 941.) Hold the tissues back with a gum retractor,

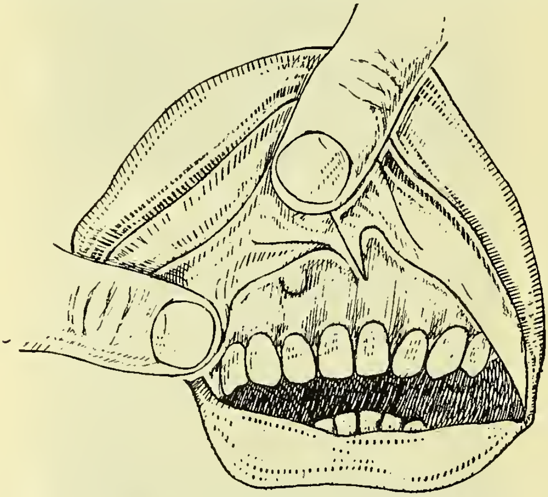


FIG. 941.—Apicoectomy. Semi-circular incision made over the apex of the root of an upper lateral incisor.

and deflect the periosteum with a periosteotome. Now remove the overlying bone with chisels, or preferably, the bone may be drilled

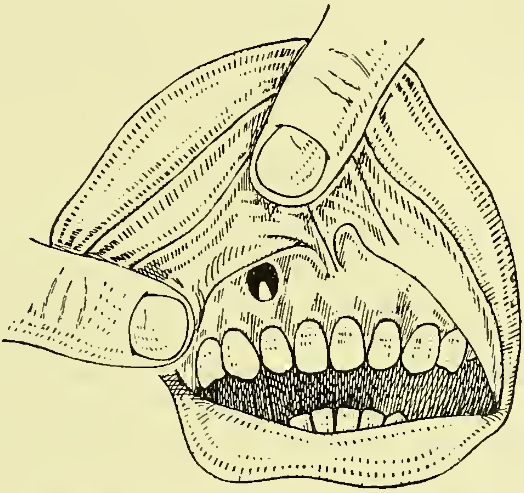


FIG. 942.—Apicoectomy. Root end exposed.

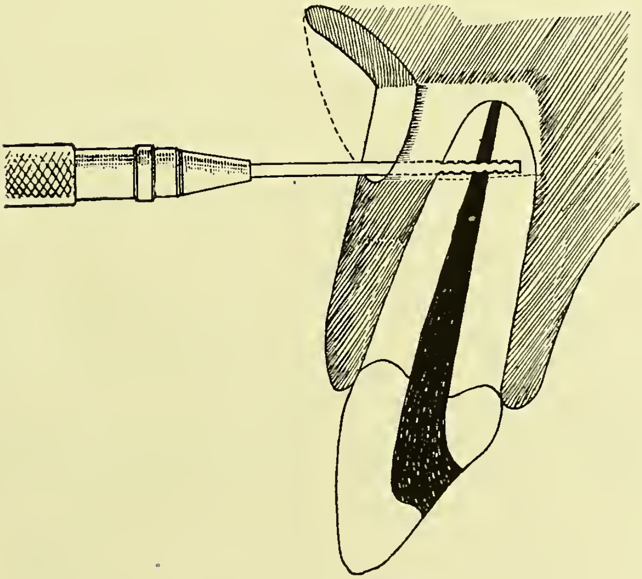


FIG. 943.—Amputating the root.

through with a surgical bur or drill. After exposing the root end (Fig. 942), cut it off with a fissure bur or Hennahan surgical drill number 4 (Fig. 943), remove the excised portion with an elevator, or excavator, and smooth up the end with a round bur. Next curette the area, removing any necrosed bone present, flush out with an antiseptic solution, and sterilize the root end with silver nitrate. In the majority of instances it is better practice to now close the gum flap and stitch together with silk. The patient should keep the mouth clean with an antiseptic wash and the healing process should be observed by occasional subjection to the X-ray.

PERICEMENTAL ABSCESS

Symptoms of Pericemental Abscess.—A discharge present is often of a whitish, glairy nature, usually midway between the apex and the gingival margin, though sometimes at the gingival margin, the condition then simulating a pyorrhea pocket. The abscess may sometimes be associated with pyorrhea beginning at the gingival margin, or with apical abscess, though a true pericemental abscess is associated with neither condition. The tooth may be dead or alive, since the active cause of the condition is often not due to death of the pulp. In true pericemental abscess, there is usually a history of trauma; in other cases a history of faulty oxidation and metabolism incident to the gouty or rheumatic diathesis. There is usually little pain, except in the acute stages. The condition may be of an acute or chronic nature. In some cases the symptoms are quite vague, the patient complaining of "something wrong" with the tooth, which, on examination, shows a whitish, glairy discharge on the gum. An examination of the affected area shows destruction of the pericementum, a roughening of the root, and the presence of calculus, which, if chemically examined, frequently responds to the murexid test for urates.

Treatment.—If discharging at the gum margin, associated with pyorrhea, and the prognosis is good, the pocket should be curetted via that route, all calculus removed, the root polished, and the usual treatment for pericementoclasia, as advocated by periodontists, prescribed. If the swelling occurs on the gum, midway between the apex and the gingival margin, a semi-circular flap should be turned back, the necrotic area curetted, calculus removed, the tissues flushed with an antiseptic, cauterized, and the flap restored to place and stitched together. The mouth should be kept in an aseptic condition, as far as possible, during healing. If in connection with a dead pulp, that condition should receive appropriate treatment. Systemic medication is sometimes indicated, the institution of derivative measures, diet and the usual regimen for faulty metabolism being resorted to.

Bibliography

1. Gies, Wm. J.: Dento-enamel circulation, Jour. Dental Research, vol. 6, no. 2, 1924–26, p. 113.
   Bödecker, Chas. F.: Dento-enamel circulation, Jour. Dental Research, vol. 6, no. 2, 1924–26, p. 113.
2. Gies, Wm. J. and Bödecker, Chas. F.: A report on further investigation on the organic matrix in human enamel, Jour. Dental Research, vol. 6, no. 2, 1924–26, p. 117.
   Gies, Wm. J. and Bödecker, Chas. F.: Practical significance of the organic matrix in human adult enamel, Jour. Dental Research, vol. 6, no. 2, 1923–26, p. 131.
   Gies, Wm. J. and Bödecker, Chas. F.: Albuminous content of human adult enamel, Jour. Dental Research, vol. 6, no. 2, 1924–26, p. 139.
   Gies, Wm. J. and Bödecker, Chas. F.: Direct evidence of the presence of albuminous matter in enamel, Jour. Dental Research, vol. 6, no. 2, 1924–26, p. 143.
3. Fish, E. W.: Trans. Royal Society Med., vol. 18, 1924–25, pp. 35–37.
4. Cape, A. T. and Kitchin, Paul C.: Histologic phenomena of tooth tissues under polarized light, etc., Jour. Amer. Dent. Assoc., Feb. 1930, p. 193.
5. Rickert, U. G.: Streptococci as I know them, Jour. Amer. Dent. Assoc., May 1929, p. 840.
6. Lyons, Chalmers J.: Jour. Amer. Dent. Assoc., 1926, pp. 1203–1218.
7. Hadley, Faith Parmerlee: Jour. Amer. Dent. Assoc., 1926, pp. 1203–1218.

Cahn, Lester R.: Effects of the degenerating dental pulp, Dental Items of Interest, Nov. 1927.

Coolidge, Edgar D.: Pulp pathology and treatment problems, Jour. Amer. Dent. Assoc., Sept. 1928, p. 1623.

Orban, Balint: Resorption and repair on surface of roots, Jour. Amer. Dent. Assoc., Sept. 1928, p. 1768.

Karshan, Maxwell: Chemistry and staining reactions of keratin, Jour. Dent. Research, April 1930, p. 181.

Editorial: Dentistry vs. the Propagandists, Dental Cosmos, vol. LXIX, no. 3, March 1927, p. 665.

Cook, Thos. J.: Dental granuloma, Jour. Amer. Dent. Assoc., vol. XIV, no. 12, Dec. 1927, p. 1859.

Rickert, U. G.: Clinical significance of the infected degenerating pulp, Jour. Amer. Dent. Assoc., vol. XIV, no. 10, Oct. 1927, p. 1895.

Rickert, U. G.: Further studies on etiology of pulp canal infections, Jour. Amer. Dent. Assoc., vol. XV, no. 6, June 1928, p. 1153.

Lyons, Chalmers J.: Apioectomy, Jour. Amer. Dent. Assoc., vol. XV, no. 1, Jan. 1928, p. 18.

Grove, Carl J.: Causes of periapical infection, Jour. Amer. Dent. Assoc., vol. XV, no. 1, p. 52.

Schroff, Joseph: Unusual cysts of the maxilla, Dental Items of Interest, Feb. 1929.

Coolidge, Edgar D: Studies of germicides in the treatment of root canals, Jour. Amer. Dent. Assoc., Feb. 1930, p. 237.

CHAPTER XXVIII

TECHNIC OF OPENING AND FILLING PULP CHAMBERS AND CANALS—FOCAL INFECTIONS OF DENTAL ORIGIN—INDICATIONS FOR ROOT FILLING—TECHNICAL PROCEDURES

ORAL FOCI OF INFECTION

Attention has been called repeatedly in this work to the close anatomic, physiologic and pathologic relationships existing between the teeth, their supporting structures and all other parts of the body. Infection surrounding the root of the tooth may, and frequently does, extend by way of the vascular and lymphatic systems, as well as by continuity of tissue, to closely associated or far distant parts. As a result, many very grave systemic disorders, either of a vague or definitely manifested nature, are produced. In view of this fact, it is important to eliminate this type of infection through proper procedures.

Certain micro-organisms, located in a root canal or in the periapical tissues, may be of a harmless nature under the conditions in which they are placed. However, according to Hartzell and Rosenau, if they succeed in entering the blood and lymph streams, and are transmitted to other tissues, they may, in their new environment, change their form and characteristics (transmutation) and be productive of great harm. A streptococcus from the tonsil or an alveolar abscess, may, under suitable cultural conditions, change to a pneumococcus, and, if it reach the lung, be productive of pneumonia, or if it reach some joint of the body, may cause arthritis deformans (rheumatism); or, in other cases, the same micro-organism may locate in the valves of the heart, be transformed under its new environment into the streptococcus viridans and result in a heart lesion; under other conditions it may travel to the inner coat of the stomach and produce an ulcer of that organ. Under similar conditions, bacilli may be changed to spirilla, and other forms of germ may take unto themselves entirely different shapes and activities. Harmless bacteria are thus seen to be frequently capable of producing great harm under changed environment, and the opposite result may also occur, viz., harmful species may lose their virulence under different cultural conditions. In septic diseases occurring in the apical space, either non-purulent or pus-forming micro-organisms are present, which, traveling to distant parts, may, under the changed conditions in which they are placed, either lose their virulence or be stimulated to increased activities. The normal resistive power of the tissues involved, in addition to other factors concerned, undoubtedly will have a definite influence on the result produced.

The following disturbances may result from focal infections located in or about the teeth:

First.—Affections of the muscles (myositis).

Second.—Affections of the joints (arthritis and synovitis).

Third.—Affections of the blood (septic anemia, endocarditis, and pleurisy).

Fourth.—Affections of the glands (lymphadenitis).

Fifth.—Affections of the nerves (toxic neuritis and degenerations).

Sixth.—Affections of the excretory organs (skin rashes and nephritis).

Seventh.—Affections of the intestinal tract (septic gastritis, enteritis, cholitis, cholecystitis and appendicitis).

In many instances systemic infections of this nature are easily recognized, diagnosed and traced to infections about the teeth, tonsils or other parts as causative agents, but perhaps just as frequently the constitutional disturbance is of a very vague nature without markedly definite manifestations. Some of the vague symptoms observable in these cases are: anemia, pallid or pasty complexion, general malaise, loss of appetite, debility, night sweats, loss of weight, low fever, (100°F.), or sub-normal temperature. Many cases of this kind have been cured by the removal of infections in the mouth, either through thorough sterilization and filling of root canals, treatment of periapical infections, extraction of the affected teeth, removal of the tonsils, eradication of pyorrhea pockets, treatment of antral disease, abandonment of faultily-constructed crowns and bridges and other sources of infection.

It is then highly important for the dentist to realize fully the great significance of the bearing which his root canal operations may have on the health and even life of his patient. It is, however, equally important for him to recognize the fact that the above-mentioned disturbances may, in many instances, have no connection whatever with oral conditions but may be due to entirely different causes, viz., the focus of infection producing the disturbance may be situated in an entirely different part of the body. The significance of conditions of this nature was not fully appreciated by either the medical or the dental profession until the memorable presentation by William Hunter.[1] A full realization of their import has, since that time, often resulted in the adoption of extremely radical measures for their relief by many men in both professions with the result that thousands of teeth have been needlessly and ruthlessly sacrificed through the extraction operation. The radical element in the medical profession has been especially guilty in this regard, referring patients to the exodontist whenever they were unable to discover other causes for systemic disturbances, as a result of lack of knowledge of oral conditions, and not realizing or recognizing the full importance of the necessity for the retention of the teeth for preservation of the continuity of the arch. A similar class of dental practitioners, prone to enthusiastically subscribe to new fads, has been equally guilty, with the result that great harm has been done. However, it would seem that a normal, sane attitude is about to be reached by both professions in regard to questions of this nature. The so-called "hundred percenter" pulpless tooth extractor is now almost an extinct species.

The solution of the problem of oral foci of infection lies in the establishment of closer affiliations between the two professions, and a closer study, on the part of both, of the diagnostic, pathologic and clinical relationships of these disturbances. An imperfectly filled pulpless tooth or a partially healed infection at the apex of a tooth always is likely to be transformed suddenly into an active source of systemic infection, if the resistive powers of the body be low, from any cause, and especially so if the normal resistance be temporarily or permanently lowered from some systemic disturbance arising after the dental operation has been performed. Operations of this nature, even if they are believed to be well nigh perfect, as revealed by the X-ray, suddenly may give trouble and become active sources of infection, in constitutional disturbances lowering the resistance of the tissue cells of the patient, since, as is well known, a few micro-organisms left in position and suddenly springing into activity, may multiply at a rapid rate and transform the apparently successful operation into a local focus of infection which may become a menace. Great caution should be exercised in determining whether teeth from which pulps are to be or have been removed, or which are affected with disturbances of the periapical tissues, should be retained in the arch or extracted. The promiscuous extraction of teeth of this type is unscientific and should be discontinued. The decision as to whether a tooth should be retained or extracted should be determined by the skill and ability of the operator to cope with the technical difficulties involved, the importance of the tooth as a part of the masticating machine, as a means of retention for artificial substitutes, the probabilities of a successful outcome as far as thorough sterilization and filling of the canals and treatment of the apical complications is concerned, and also on the systemic condition of the patient. Figs. 944 and 945.

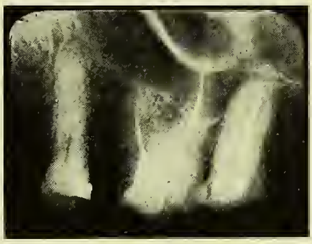


FIG. 944.—Root canal fillings.

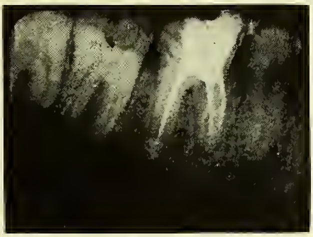


FIG. 945.—Canal fillings in molar showing two canals in mesial root.

DIAGNOSIS AND PROGNOSIS

The use of the X-ray is the most valuable diagnostic measure in these instances and it should be resorted to for this purpose at the beginning of all cases, where root canal work is to be attempted. Anterior teeth with straight, well-developed roots, offer the best prognosis, the bicuspids next, while molars, owing to the technical difficulties involved, afford the poorest chances of a successful outcome. Figs. 946, 947 and 948. Pyorrhetic teeth, affected with apical complications, are usually poor risks, and in many instances had better be extracted at once. Types of cases usually unfavorable for treatment are those in which there is too much dead apical cementum, resulting from extensive chronic alveolar abscess and other types of low grade infection, those on which

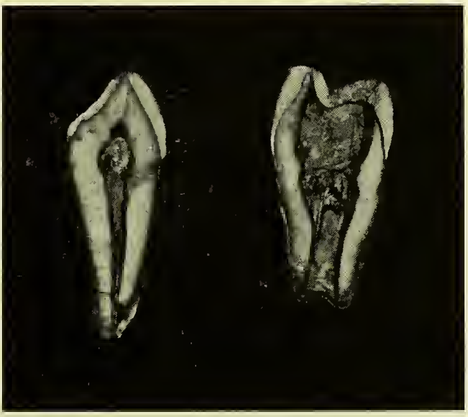


FIG. 946.—Sections of natural teeth (lower) showing pulp chamber and canals.

there is a large amount of dead alveolar cementum as exhibited in pyorrhea cases, and teeth with abscesses opening into the antrum. (Figure 949.) In cases of this nature, the pericementum is often extensively destroyed, the cementum encrusted with calculus, necrotic, and pus-soaked, and in a condition which it is impossible to restore to the normal state. In the latter types, apicoectomy or extraction usually is advisable. In the milder forms of chronic apical infection, and even in some of the cases of more extensive granuloma, the operation of excision of the root end may be performed and the tooth restored to prolonged periods of usefulness. (Figure 950.)

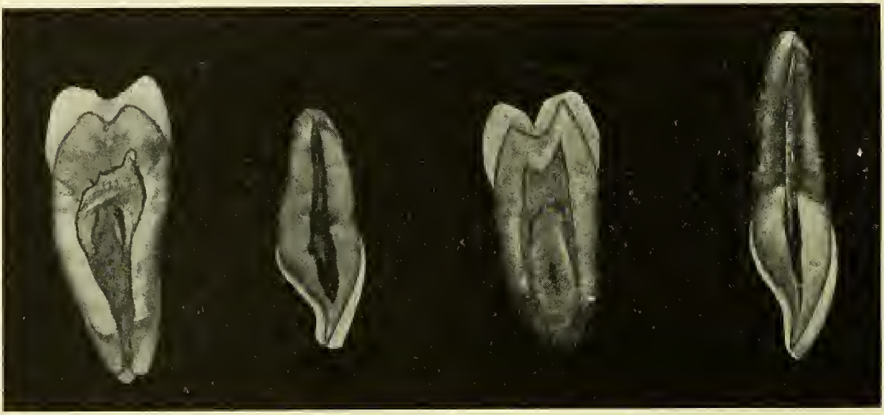


FIG. 947.—Sections of natural teeth showing pulp chambers and canals.

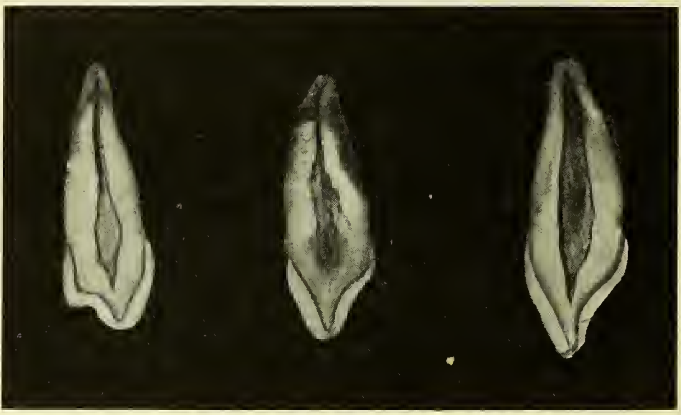


FIG. 948.—Sections of natural teeth showing pulp chamber and canal.

In reading the radiogram, which should be made in every instance, teeth known to be normal should be studied first, with the assistance of a reading glass or dentiscope. On a normal tooth, the peridental membrane may be seen as a continuous radiolucent line encircling the root. Surrounding this will be noted the lamina dura, exhibited in the form of a radiopaque line. The trabecula of bone at the apex outside of this line should appear homogeneous with the surrounding bone.

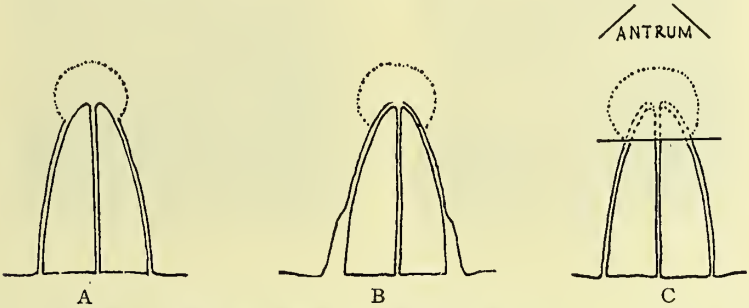


Fig. 949.—Sketch showing unfavorable cases for treatment. A, periapical infection with denuded root end; B, periapical infection on pyorrhetic tooth; C, abscess opening into the antrum.

In some instances the apical space surrounding teeth recently infected or infected with micro-organisms of low virulence may appear perfectly healthy in the roentgenogram while teeth suffering from the effects of traumatic occlusion, or chronic inflammatory disturbances of the apical tissues may exhibit an apparent rarefying process in the surrounding bone, simulating infection. Consequently, it should be remembered that the appearance of a radiolucent area at the apex does not always signify the presence of infection. Many errors in diagnosis are thus made from an imperfect understanding of this fact. The radiogram is, then, not an infallible guide in the diagnosis of infective conditions of the

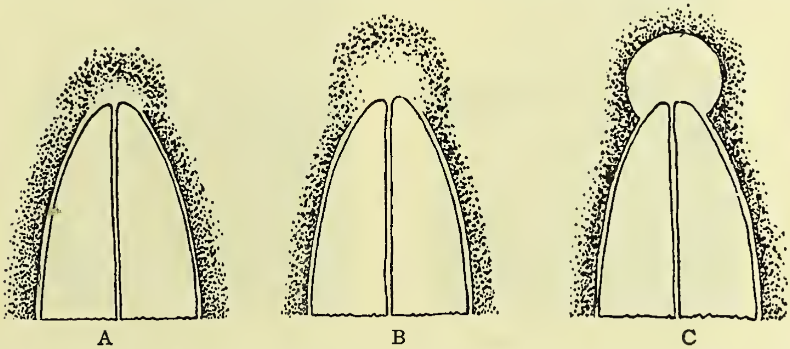


Fig. 950.—Three types of infection in the periapical tissues. A, small rarefied area confined to apex of root; B, more extensive involvement with denuded root end; C, cyst.

periapical tissues. The radiogram is merely a shadow-picture. Absolute diagnosis of infection and the presence of pathologic micro-organisms is made with the microscope. Figs. 951 to 956.

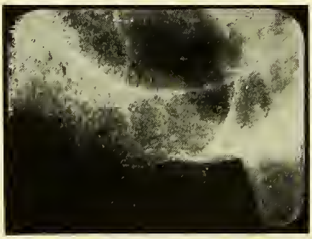


FIG. 951.—Large circular dark area is antrum and root cyst.

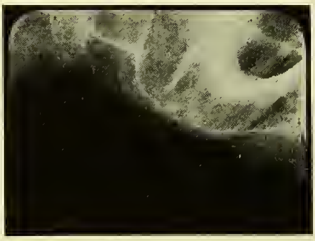


FIG. 952.—Example of very low antrum.

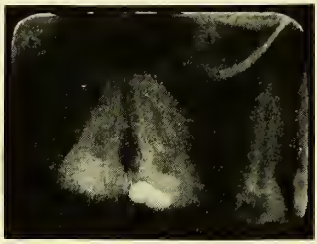


FIG. 953.—Low antrum simulating multilocular cyst.

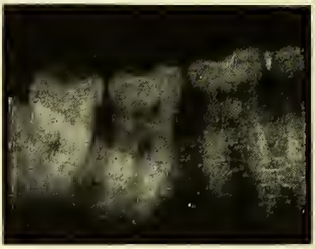


FIG. 954.—Overlapping of root bifurcation of first molar, giving appearance of pulp nodule.

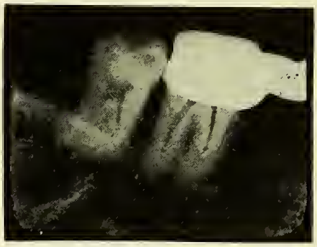


FIG. 955.—White line obscuring apices of third molar is internal oblique line.

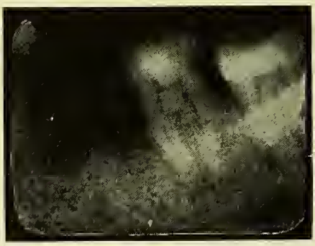


FIG. 956.—Overlapping of bifurcation of roots in second molar, giving appearance of large pulp stone.

An area of absorption, although present, may not be revealed by the roentgenogram because of (*a*) incorrect angulation in making the exposure, (*b*) of being hidden by a part of the suspected tooth, such as another root, (*c*) presence of a heavy mass of intervening bone, such as the malar process, or (*d*) a layer of condensing osteitis covering and obscuring the rarefying osteitis. A tooth with apparently visible absorption at its apex is not necessarily infected. Absorption as well as condensation may be caused by irritating medication or by trauma. Figs. 957 to 960.

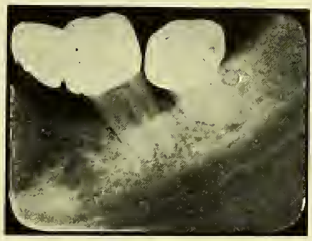


FIG. 957.—Horizontal dark area is inferior dental canal.

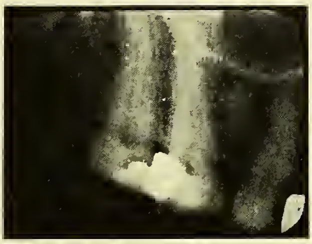


FIG. 958.—Root which has undergone calcification, simulating condensed bone.

When it is decided to attempt the preservation of teeth affected with septic conditions at the root end, the responsibility should be assumed alike by patient and operator, and the possibilities of future complications fully explained. The case should be X-rayed at the termination of the operation, again at intervals of one, three, six, and twelve months, and again at occasional periods. A successful termination will be indicated by progressive filling-in of the affected area with new bone formations, which should be complete and homogeneous after periods ranging from one to three years. In case these procedures cannot be followed, it may be deemed the part of wisdom to extract, rather than assume the risk of subsequent complications.

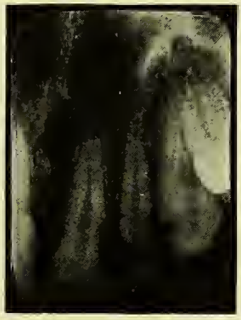


FIG. 959.—Anterior palatine foramen mesial to central, often mistaken for granuloma.

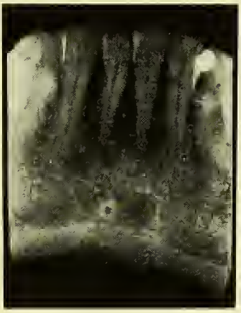


FIG. 960.—Genial tubercles, sometimes mistaken for bone condensation.

As a rule, teeth affected with granuloma had better be extracted, if present in the mouths of patients suffering from arthritis, heart, kidney, or splenic affections, or some other form of grave disturbance for which definite causes cannot be found. Patients of the above type are peculiarly susceptible to infections, and the dentist is not justified in subjecting them to additional possible sources of infection. The cooperation of the physician and laboratory technician should be secured in making a decision in cases of this nature. Great significance should be attached to the urinary analysis, the blood picture and blood pressure indications. The majority of patients suffering from streptococcal infections exhibit low blood pressure, low hemoglobin index and deficiency of red and white blood cells, with a lymphocytosis. The minority vary from normal to very high blood pressure with an exhibition of leucocytosis. According to Weston A. Price[2] the most frequent hematological blood changes from dental infections are leucopenia, erythropenia, lymphocytosis and hemophilia. The same authority states that in these conditions, the principal chemical blood changes are reduction of the alkali reserve, development of an acidosis, increase in blood sugar and uric acid, and development of nitrogen retention and of products of imperfect oxidation. It also should be realized that the danger of a focus of infection frequently depends not so much on the size of the granuloma, as revealed by the X-ray, as it does on the virulency of the organism producing the disturbance, the tolerance of the tissue cells, and the tension under which the infection is operating.

A review of the immense amount of literature on focal infections and pulp canal therapy with which the pages of dental and medical publications have been flooded since 1910, when Sir William Hunter's paper started this agitation, would be a monumental task. The dental profession has ever been wont to follow new and strange gods. In this instance, stirred into hysterical activity by sensational articles appearing in the public press and the journals, written in many instances by irresponsible or ignorant demagogues, and often aided and abetted by pseudo-scientists in both the medical and dental professions, many of whom were sincere but ill-informed, what might be termed a focal infection fetish or phobia arose, which might be compared to some features of the abolition crusade preceding the war between the States, or to certain phases of the late prohibition movement. As a consequence, a furore of extraction seized both professions, carrying along with it many of the more sane, conservative and scientific minds in both, with the result that specialists in exodontia, tonsillectomy oral surgery, and prosthodontia developed overnight, whose duty it was in many instances to unthinkingly remove these suddenly discovered and often unoffending and innocent supposed causes of imaginary ills and to supply the loss of needlessly sacrificed teeth with inadequate but beautifully designed, engineered and constructed artificial substitutes of gold, vulcanite and porcelain. The offending tonsils, which for some evidently mysterious reason had been needlessly placed by nature between the pillars of the fauces, suffered equally with the teeth in the mutilating efforts of the enthusiasts of the new creed; but unfortunately their loss could not be even partially compensated for by the highly developed artistic and mechanical skill of the trained "engineers" in either the dental or medical professions. As a result of this reign of terror, thousands of human victims have ruthlessly been sacrificed and deprived of teeth and tonsils and the ability to masticate, but in many instances with no relief whatever from the vague disorders from which they had previously been suffering, the exact nature of which the science and diagnostic ability of the new creed in dentistry and medicine had not been able to determine, but had unwittingly and erroneously attributed to these frequently innocent but valuable members of the human body.

During this era of destructive dentistry, much valuable information was being accumulated, through the efforts of the histologists, bacteriologists, pathologists, and a few level-headed, sane and scientific-minded men in the fields of preventive and operative dentistry and of root therapy. Slowly but surely suspicion has now been supplanted by conviction that many of the ills to which the human race, as well as rabbits, guinea pigs, rats, monkeys and other lower animals, were sacrificed for focal infection experiments, are not due to infected teeth and tonsils. Unquestionably the tide has turned and a rational tone is evidencing itself in the literature published during the past few years and in the minds of thinking men in both professions. Even Doctor William Hunter has appeared in a timely article, published in The Dental Magazine and Oral Topics, November, 1929 to have noticeably receded from his original attitude. Through the devoted and untiring efforts of such men as Edgar D. Coolidge[3] J. R. Blaney,[4] Edouard M. Hall,[5] J. P. Buckley,[6] Carl J. Grove,[7] Edward H. Hatton,[8] William G. Skillen,[9] U. G. Rickert,[10] P G. Puterbaugh,[11] O. H. Moen,[12] Elmer S. Best,[13] and others, who have contributed valuable research knowledge in articles appearing in the journals during the past eight or ten years, root therapy, the treatment of periapical disturbances and the filling of root canals is being greatly improved and placed on a more nearly scientific basis than it formerly occupied. It is now fully realized by many that the sacrifice of teeth for fear that they may produce harm is both unsurgical and unscientific, and the old surgical axiom "Save what can be saved" is being re-established. The solution of the problem lies in continued research into the questions involved and in a further improvement in the technical procedures incident to the treatment of diseased pulps and the filling of pulp canals.

Operative Dentistry, which experienced a marked decline during these periods of stress is now destined to return to her rightful position and to assume the important place which she justly deserves, through the institution and perfection of measures designed to *prevent* pulp diseases. This is a great responsibility, but she. in the near future, will, through early preventive and restorative measures be enabled, in the majority of cases, to maintain the integrity of the enamel, the normal protective agent against diseases of the dentin and pulp. May we speed the day when the efficiency of the human masticating machine may be sacredly preserved and when the physiologic action of the tonsil may be discovered and maintained.

TECHNIC OF OPENING AND FILLING PULP CHAMBERS AND CANALS

In the performance of the various technical procedures incident to opening and removing the contents of the pulp chamber and canals, one of the following conditions will be present:

First.—The pulp is vital, but diseased, and has been anesthetized with novocain hydrochlorid preliminary to removal; or

Second.—The organ is non-vital and supposedly non-infected, viz., in a state of dry gangrene; or

Third.—It is infected and putrescent; or

Fourth.—It is non-vital and has been the cause of periapical disease.

There is no operation in the entire field of dentistry or surgery which requires greater skill than that of the proper opening and filling of root canals. There is none which has a more far-reaching influence on the future health and well-being of the patient. The non-removal of pulp remnants, the imperfect opening, enlarging and sterilization of the canal or the failure to hermetically seal it for its entire length, results in the leaving of an inviting field for the continuance or establishment of a septic condition, which may later undermine the health and produce even death of the patient. through the absorption of toxic products into the system, by way of the lymphatics and blood streams in the tissues of the apical space. (Figure 961.) The importance of a thorough realization of the bearing of the operation on general health conditions

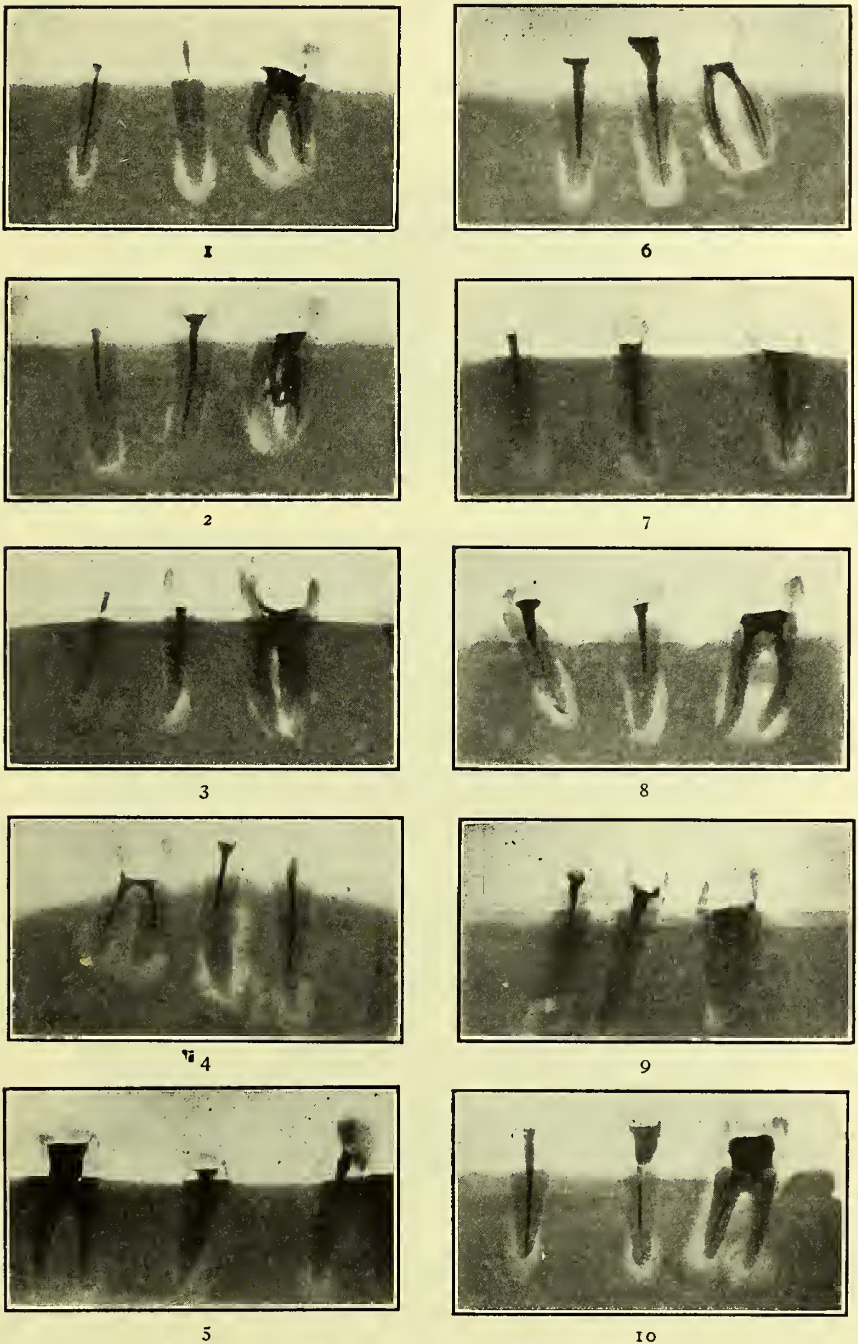


FIG. 961.—The apices of these teeth were surrounded with wax and the roots were embedded in plaster of Paris by ten students of the Sophomore Class. The canals were then opened and filled, following which they were radiographed and the poor results shown to the students, affording an excellent objective demonstration from which the obvious moral was easily drawn.

may be at once clearly perceived from the previous discussions of focal infections.

Pulpless teeth with anomalous roots impossible to properly treat and fill, should be extracted without hesitation. (Figures 962 to 968.)

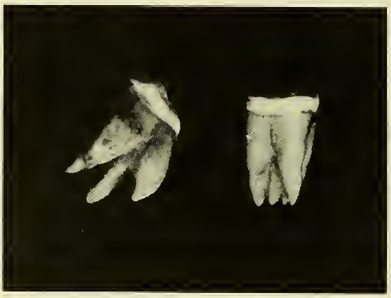


FIG. 962.—Multi-rooted teeth.

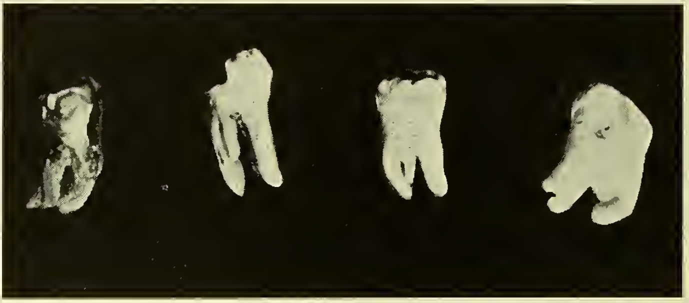


FIG. 963.—Multi-rooted teeth.

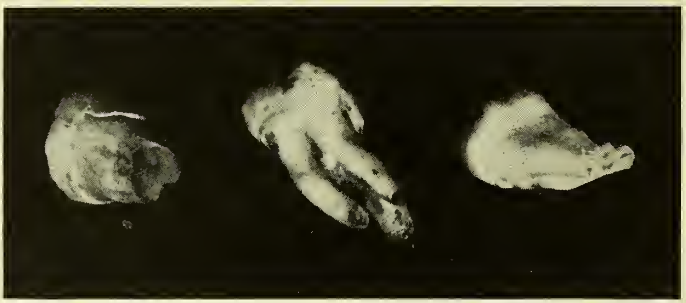


FIG. 964.—Incompletely developed roots in young teeth.

Teeth affected with incurable pathologic disturbances in the canals or apical space should be unhesitatingly removed. The possibility of the existence of an excessive number of roots, as well as concealed roots canals, should be borne in mind constantly, and redoubled care exercised in an attempt to discover an opening. It should be remembered also that the majority of roots exhibit more than one apical foramen, oftentimes many minute accessory canals in the apical third, or even occasionally in the mid-root, being present. These are, in the present state of development of our technical skill, impossible to fill; however, a realization of these anatomical conditions should redouble the painstaking care exercised in canal sterilization and filling procedures. Perfect filling of the root canals will seal their inner orifices and block them off

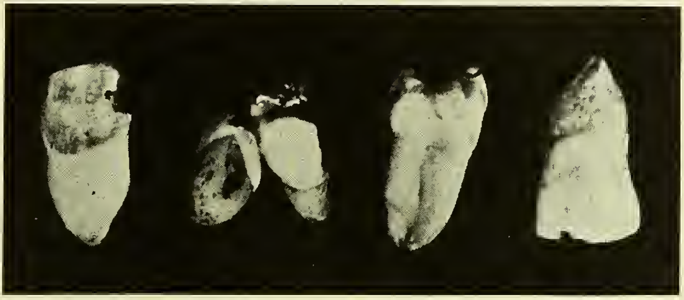


FIG. 965.—Malformations, showing two dwarf central incisors, twin teeth, and fused roots of a bicuspid, with separate apices.

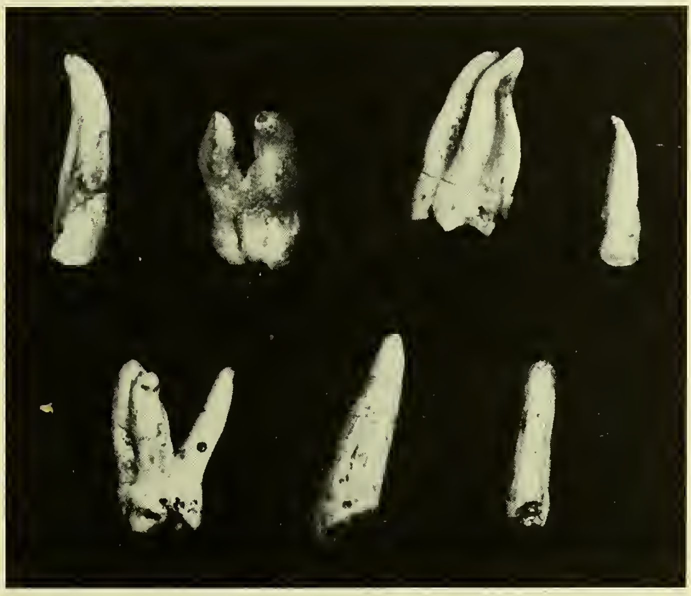


FIG. 966.—Anomalies.

from further connections with the seat of trouble. Figs. 969, 970 and 971.

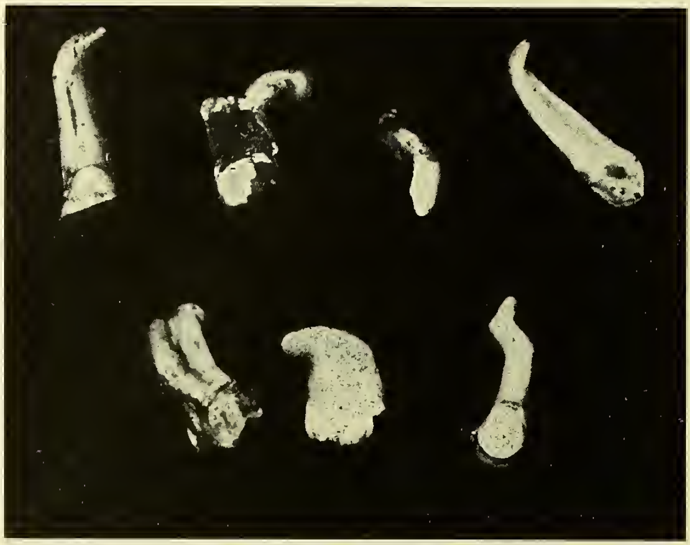


FIG. 967.—Crooked roots.

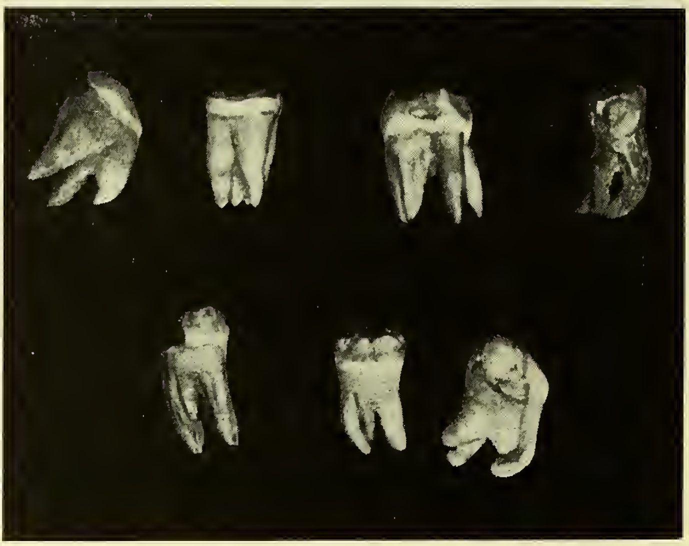


FIG. 968.—Multirooted teeth.

Dentino-cemental Junction.—Much has been written in regard to the histologic relationships existing between the dentin and cementum. Harold Box[14] claims that there are definitely communicating channels between the lacunae and canaliculi of the cementum and the tubules

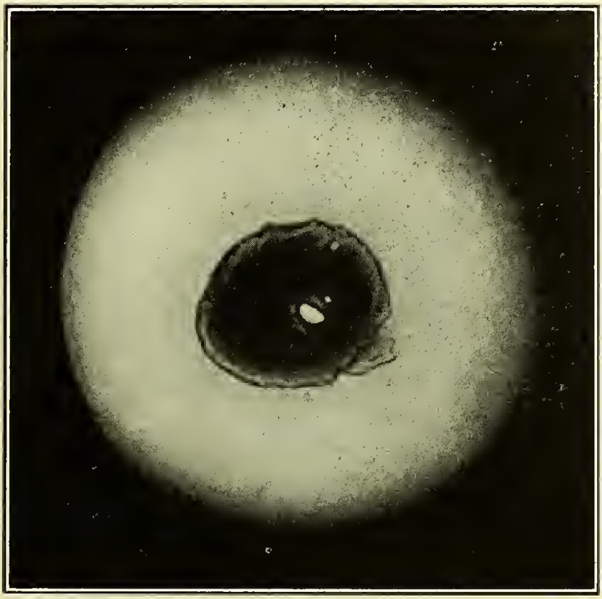


FIG. 969.—Low power photomicrograph, showing multiple foramina at apex of root. (Courtesy of Dr. John B. Stein.)

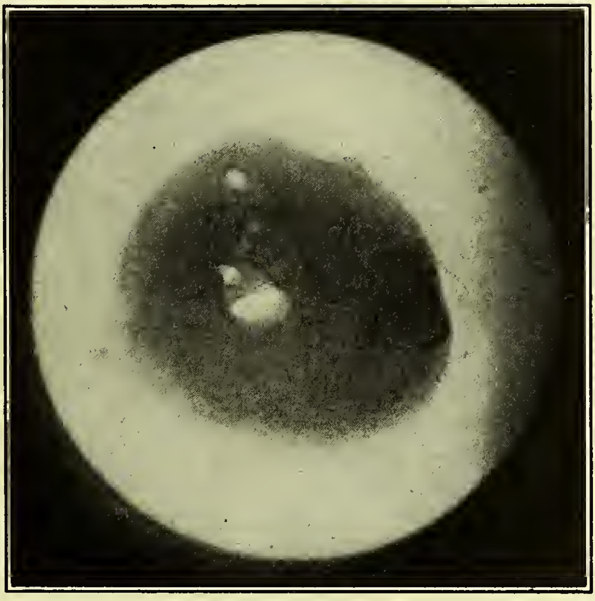


FIG. 970.—Multiple foramina at root apex. (Courtesy of Dr. John B. Stein.)

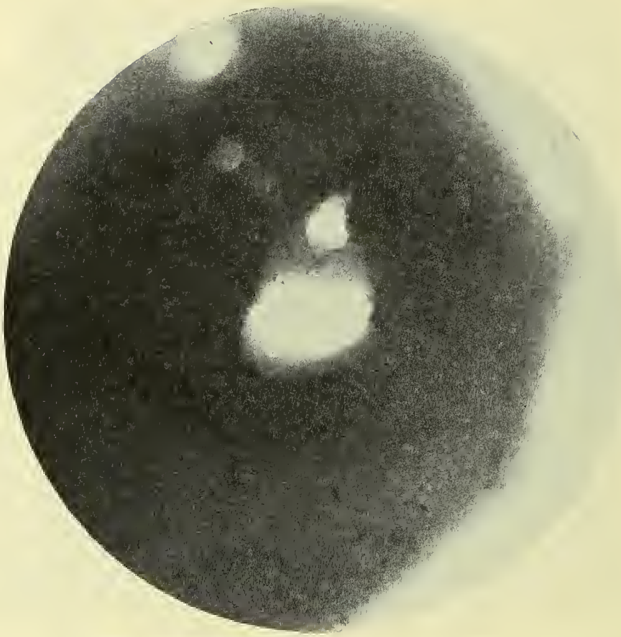


FIG. 971.—Multiple foramina at apex of root. (Courtesy of Dr. John B. Stein.)

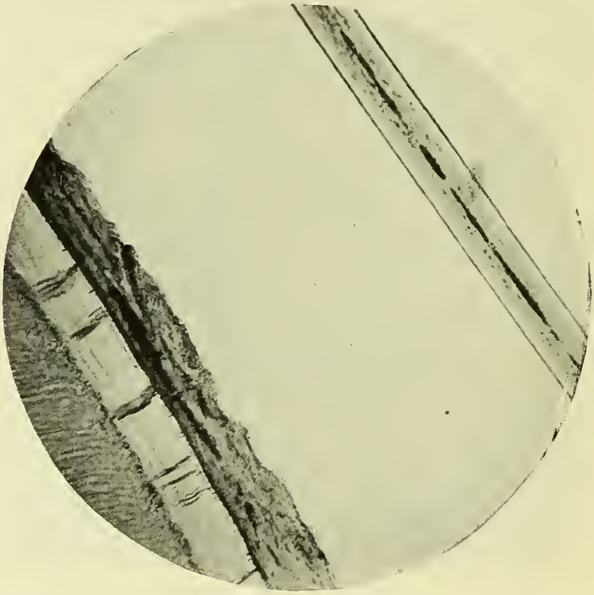


FIG. 972.—Showing comparative thickness of a human-hair, seen to the right, and noncellular cementum covered with pericementum, seen on the left. (Courtesy of Dr. Harold K. Box.)

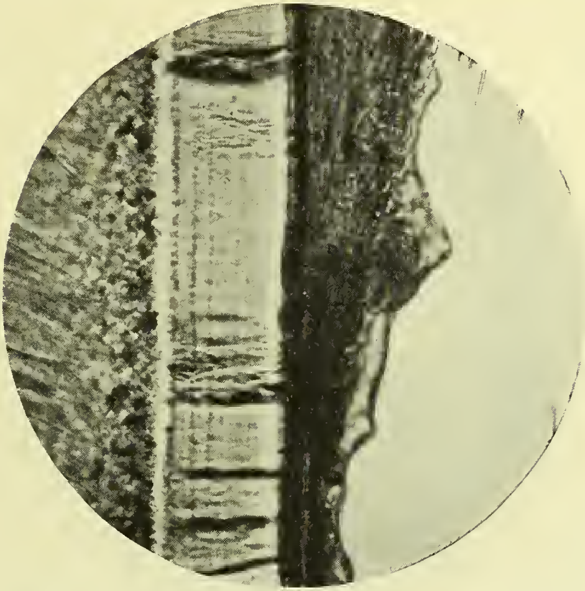


FIG. 973.—Non-cellular cementum of gingival and middle third of the root. Dentin to the left, pericementum to the right. (Courtesy of Dr. Harold K. Box.)

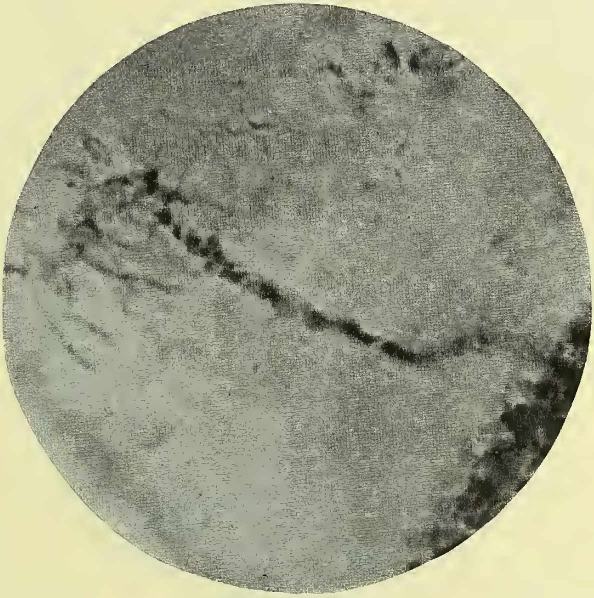


FIG. 974.—Long canaliculus extending from pericementum on right to a cemental lacuna on left. (Courtesy of Dr. Harold K. Box.)

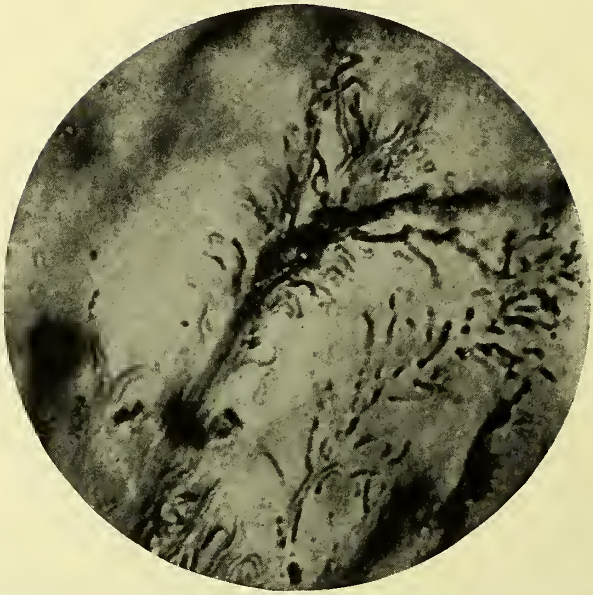


FIG. 975.—Spindle shaped enlargements at periphery of dentinal tubules at dentino-cemental junction. (Courtesy of Dr. Harold K. Box.)

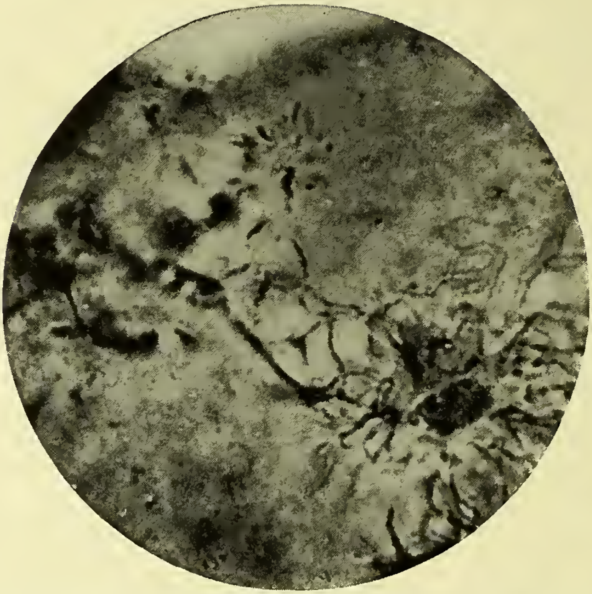


FIG. 976.—Dentino-cemental communication. On the left, spindle-shaped termination of a dentinal tubule; on the right, cemental lacunae and canaliculi; in the center, dentino-cemental passage. (Courtesy of Dr. Harold K. Box.)

of the dentin of the apical third of the root. Price[15] states that the dentino-cemental junction acts as a fire-wall, with only a few channels passing through from the pulp to the pericementum in the form of accessory canals having no definite communication with the dentinal tubules and the cemental lacunae. Mummery, Hopewell-Smith, Williams, Bödecker and others have discussed the nature of the dentino-cemental junction and are in disagreement. The consensus of opinion at the present time is that the cementum overlying the dentin of the gingival and middle thirds is largely structureless and non-cellular and offers no nutritional or osmotic communication with it. However, in the apical third, the cementum is of the cellular type, contains lacunae and canaliculi, and is perforated by numerous accessory and lateral foramina leading to the pulp. Figs. 972 to 976. Consequently, in filling root canals of pulpless teeth with uninvolved and healthy apical

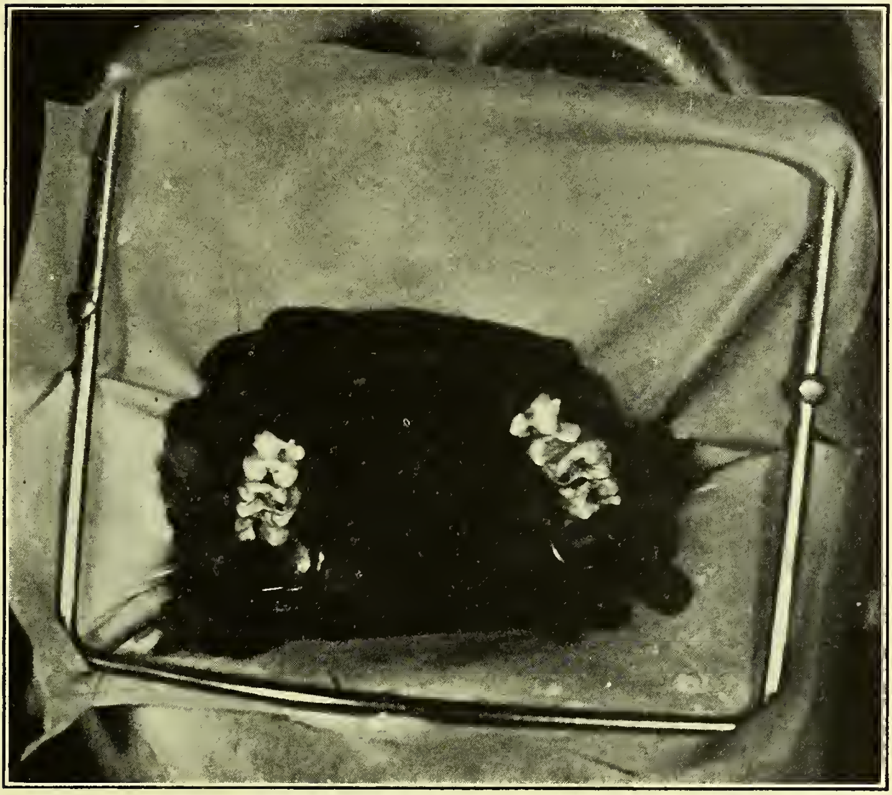


FIG. 977.—Rubber dam applied for root canal therapy on a tooth on each side of the jaw. The angle from which the photograph was made makes it appear as if the dam extended too high, which is not the case. However, the nostrils of the patient are covered, thus protecting the operator from the exhalations of the patient.

spaces, special attention should be given to perfect filling of the apical third and the sealing of the inner orifices of any accessory foramina or canals that are likely to be present in this locality. Also, owing to the presence of this close and intimate connection between dentin and cementum in the apical third, there is always danger from leaving this so-called "critical" end of the root in cases of chronic periapical involvement, on account of its pronounced tendency to become infected throughout its substance. In view of this danger, it will often be advisable to perform excision of the root end (apicoectomy) in cases of chronic alveolar abscess and similar periapical infections or to extract the tooth.

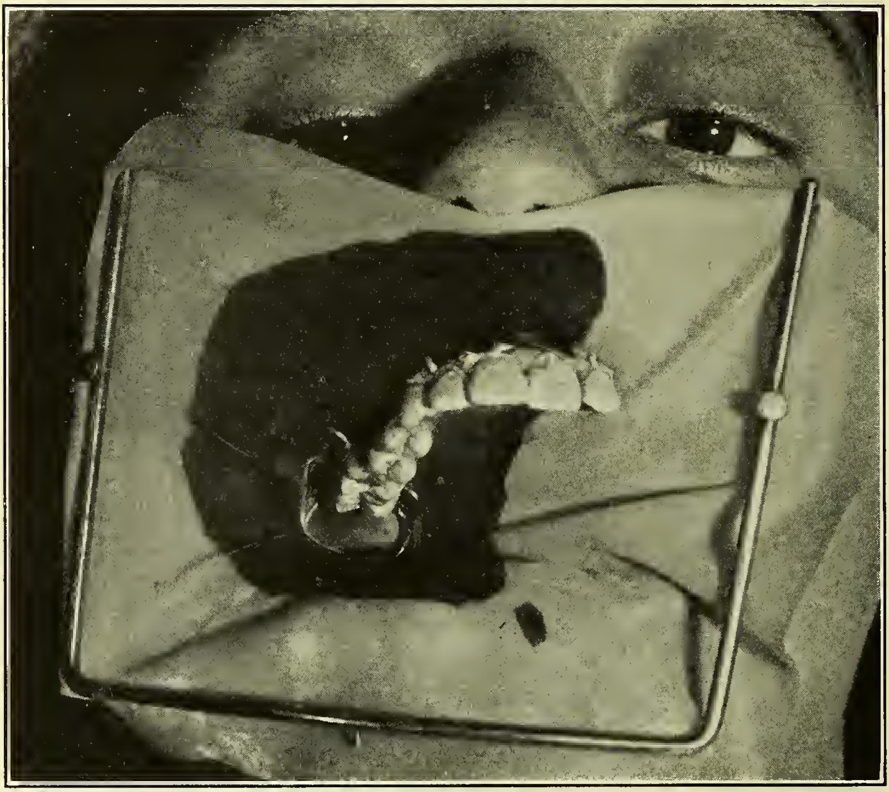


Fig. 978.—Rubber dam applied and field sterilized with tincture of iodine. With the Young frame shown, the dam does not cling closely to the face of the patient. Among the many advantages of this arrangement is the important one that the dam may be extended over the nostrils without discomfort to the patient and thus protect the operator from the exhalations of the patient.

ESTABLISHING AN ASEPTIC TECHNIC

Owing to the conditions under which the dentist is constantly working, the establishment of a perfect aseptic root canal technic is very difficult or almost an impossibility. However, every effort should be made to accomplish as nearly ideal conditions in this respect as possible. The dentist is no more justified in introducing infection by way of the root canal than is the surgeon in doing so by way of the integument.

The following technic for establishing and maintaining asepsis during root canal work may be followed with assurance of excellent results:

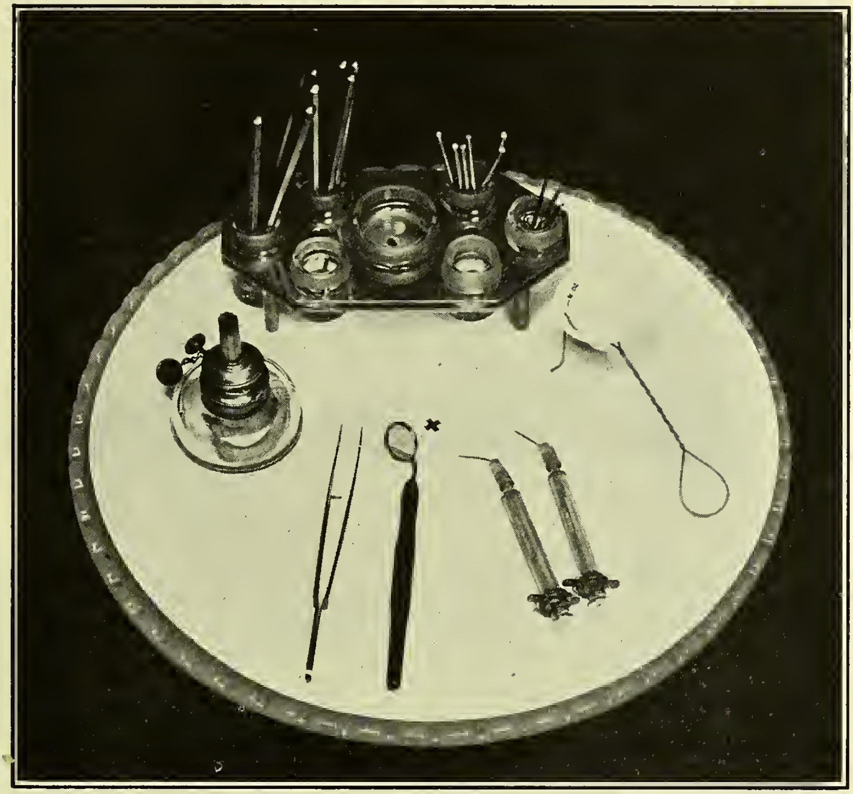


FIG. 979.—Bracket table "dressed" for root therapy operation.

1. Seal into the cavity for two or three days before the operation, eugenol or a 10% solution of beechwood creosote, as suggested by Grieves, thus sterilizing the coronal dentin; or in cases of putrescence, formocresol or some of the other remedies previously mentioned may be used.

2. At the next sitting spray the mouth with an antiseptic solution, apply the rubber cloth and sterilize the teeth included in the dam with tincture of iodin followed by alcohol. Figs. 977 and 978.

3. Now open into the pulp chamber and canals, following the technic to be described, having the hands, all instruments, towels, head-rest covers, dressings, paper and root canal points sterlized before proceeding.

Cotton dressing, gauze packs, absorbent points, towels, linen and napkins should be sterilized in an autoclave. The larger instruments should be boiled for twenty minutes or subjected to steam pressure in a suitable sterilizer. Broaches and other small root canal instru-

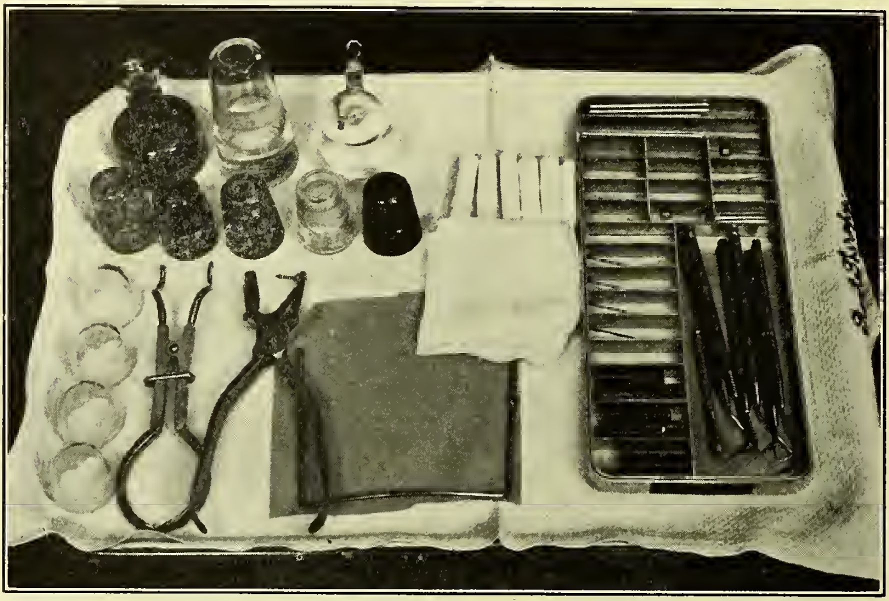


FIG. 980.—Top of operating cabinet "dressed" for root canal surgery. Instruments, appliances, dam, towel and dressings have been autoclaved.

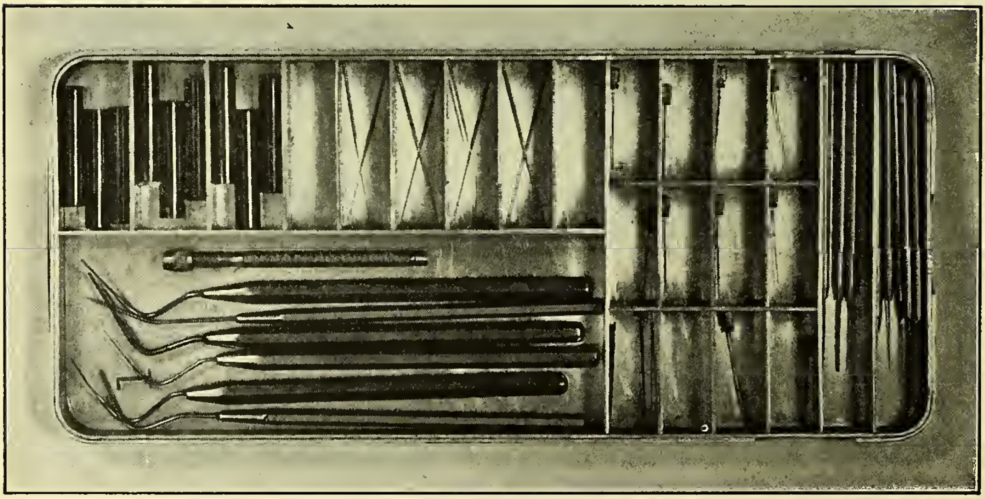


FIG. 981.—Sterilized tray and instruments for root canal surgery.

ments, after boiling may be stuck into the under side of the cork of a bottle of convenient size, carrying alcohol. Long-handled broaches may be set in bottles or containers containing alcohol ready for use. The finger tips should be immersed frequently in alcohol throughout the operation. Rubber gloves may be worn, though they have a tendency to dull the delicate sense of touch required in these operations. Broaches and similar small instruments may be repeatedly passed through a flame or dipped in alcohol and flamed throughout the operation. Figures 979 to 982 illustrate the operating bracket, top of cabinet and instrument trays as used in the pulp therapy clinic of the dental school of a large university.

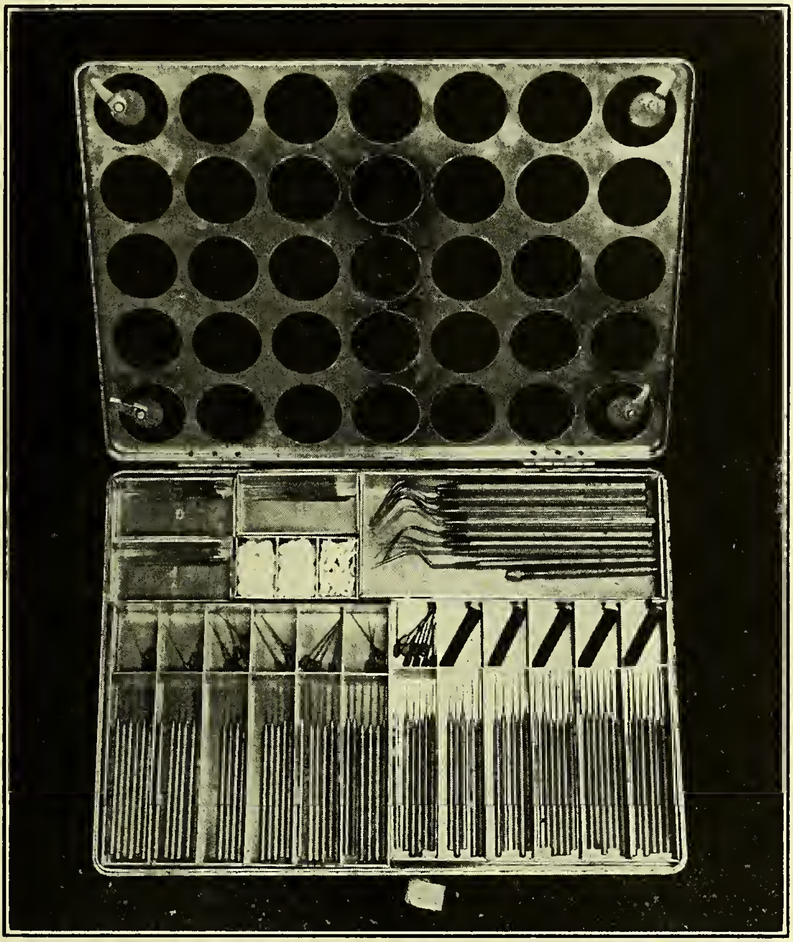


Fig. 982.—Large instrument tray containing instruments and small dressings for root therapy.

TESTS ON STERILIZATION OF INSTRUMENTS

At the request of the Department of Pulp Canal Therapy, Doctor K. W. Small of the Department of Bacteriology of New York University made bacteriologic tests to determine the efficacy of flaming in alcohol and of sterilizing root canal instruments in the open flame. The preliminary report of Doctor Small follows:

"Five types of instruments were tested with two methods of sterilization, one, passing back and forth in the flame of an alcohol lamp and the other, dipping in alcohol and igniting. Both streptococcus viridans and streptococcus hemolyticus were used as contaminating organisms. In each case eighteen hour broth cultures and the growth on the surface of agar plates were used.

"Controls on the sterility of the instruments after boiling fifteen minutes were made. In addition, to be sure that the instruments were successfully contaminated, cultures were made from them after dipping in the broth and touching the growth on the plates.

Instrument	One flaming				Dipping in alcohol and igniting				
	Strep. viridans		Strep. hemo.		Strep. viridans		Strep. hemo.		
	Broth	Plate	Broth	Plate	Broth	Plate	Broth	Plate	
Smooth broach.........	–	–	–	–	–	–	–	–	o
Barbed broach.........	+	–	–	–	–	–	+	+	37 %
Light Kerr file.........	–	–	–	–	+	–	+	–	25 %
Medium Kerr file.......	–	–	–	–	+	+	+	+	50 %
Heavy Kerr file........	+	–	+	–	+	–	+	+	62 %
	40 %	0	20 %	0	60 %	20 %	80 %	60 %	

+ Recording growth of the organisms originally used to contaminate instruments.

"From a bacteriological standpoint these results would make it appear that the effective factor in the sterilization of the instruments was heat. The percent of successful sterilizations was consistently higher in the plain flaming method than in the ignition of alcohol. The alcohol is not in contact with the instruments long enough to exert an antiseptic action. The temperature at which alcohol ignites and burns is too low to be effective at such a short duration. As a rough indication of this, a thermometer was dipped in alcohol at room temperature and ignited. The temperature did not exceed 80°C.

"The type of instrument used affected the resistance to sterilization due to varying thickness of metal and to the presence of crevices. The smooth broach was most effectively sterilized, then the light Kerr file, next the barbed broach, then the medium Kerr file and last the heavy Kerr file.

"When the instruments were contaminated with growth on agar plates, sterilization was more effective with both methods than when broth culture was used. This may have been due to the organisms being protected by coagulated agar, which may adhere to the instrument when touching the culture."

Doctor Small was then requested to make bacteriologic tests on the efficacy of Lysol for the same purpose. Her report is as follows:

BACTERIOLOGICAL TESTS ON THE EFFICACY OF LYSOL IN THE DISINFECTION OF DENTAL INSTRUMENTS

"The following tests were carried out with the idea of determining what concentration of lysol would be effective in a reasonably short time in the sterilization of instruments contaminated with cultures of staphylococcus aureus. The instruments used were coarse, medium, and fine pulp canal files, and the cultures were eighteen hour broth cultures and heavily inoculated shake tube cultures.

"All instruments were sterilized by boiling and one of each type was used as a sterility test by inserting it into a tube of sterile broth. All instruments were allowed to stand in the "test" broth for one hour after they had been subjected to the treatment specified. The broth was incubated at 37°C. and readings recorded at 48 hours. In one case where they were left in the broth over night some tubes showed growth, whereas a duplicate set, which had been in contact with the broth for one hour were all negative. Therefore, as a final check in each case, when the whole series in a certain concentration of lysol for a certain time of exposure gave negative results with the usual procedure, a duplicate, in which instruments were in the broth for eighteen hours, was run.

"Under these conditions, it was found that 0.5% lysol was effective in 30 minutes while 2% lysol was effective in 6 minutes.

"This would apply to actual disinfection of contaminated instruments. If lysol were being used merely to prevent contamination of previously sterilized instruments probably the 0.5% would be effective."

TESTS MADE WITH THREE TYPES OF INSTRUMENTS IN TWO DIFFERENT CONCENTRATIONS OF LYSOL FOR VARYING PERIODS OF TIME.

		Canal files	1 %	2 %	3 %	5 %		6 %		10 %	15 %	20 %	25 %		30 %	
0.5 % Lysol	18 Hour broth culture	Coarse.......	+	+	+	+				−	+	−	−	+#	−	−#
		Medium......	+	+	+	+				+	−	−	−	−	−	−
		Fine.........	+	+	+	+				+	−	−	−	−	−	−
	18 Hour shake tube	Coarse.......	+	+	+	+				+	−	+	+	+	−	−
		Medium......	+	+	+	+				−	+	+	+	+	−	−
		Fine.........	+	+	+	−				−	+	−	−	−	−	−
2 % Lysol	18 Hour broth culture	Coarse.......	+	−	−	+#	−	−	−#							
		Medium......	+	−	−	−	−	−	−							
		Fine.........	−	−	−	−	−	−	−							
	18 Hour shake tube	Coarse.......	+	+	−	+	−	−	−							
		Medium......	+	−	+	+	−	−	−							
		Fine.........	−	+	−	−	−	−	−							

+ = growth.
# = instruments in contact with broth over night instead of for one hour.

ROENTGENOGRAPHIC DIAGNOSIS

The introduction of the X-ray has resulted in great improvement in the methods of diagnosis and treatment of these conditions. All roots which are to be treated and filled should be subjected to the Roentgenray at the beginning, and at frequent intervals during the various procedures, as well as at the completion of the root-filling operation, in order that the progress of the work may be revealed and the final results shown.

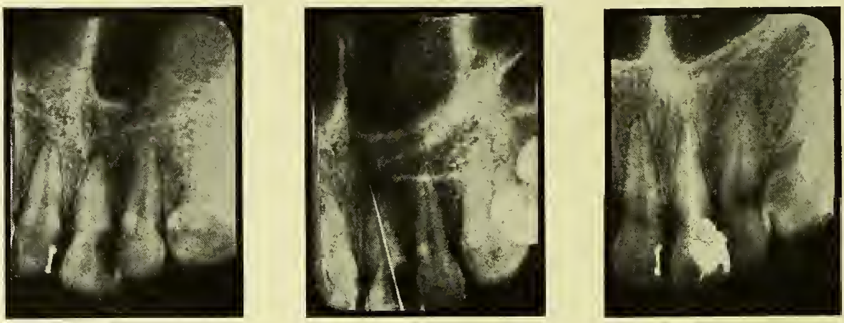

A B C

FIG. 983.—Series of radiograms showing root therapy on an upper central incisor. A, exposed pulp; B, diagnostic wire in position; C, canal filled.

After exploring, opening and enlarging the canals, sterile diagnostic wires should be inserted to the end of each root canal and a radiogram taken, to make sure that the results desired have been obtained. If the radiogram indicates that the canals have not been opened to their extremities, additional work is then required to accomplish the result, at the termination of which the sterile diagnostic wires are again applied and the tooth subjected to the X-ray a second time, to note progress.

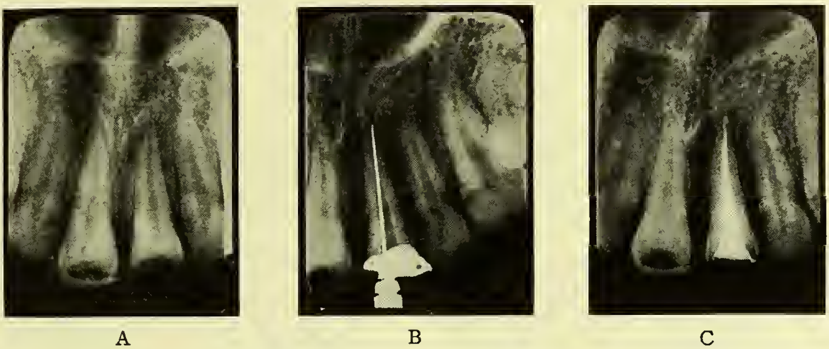


Fig. 984.—Roentgenograms showing root canal surgery on an upper central incisor. Patient age twelve. A, gangrenous pulp; B, diagnostic instrument in position; C, canal filled.

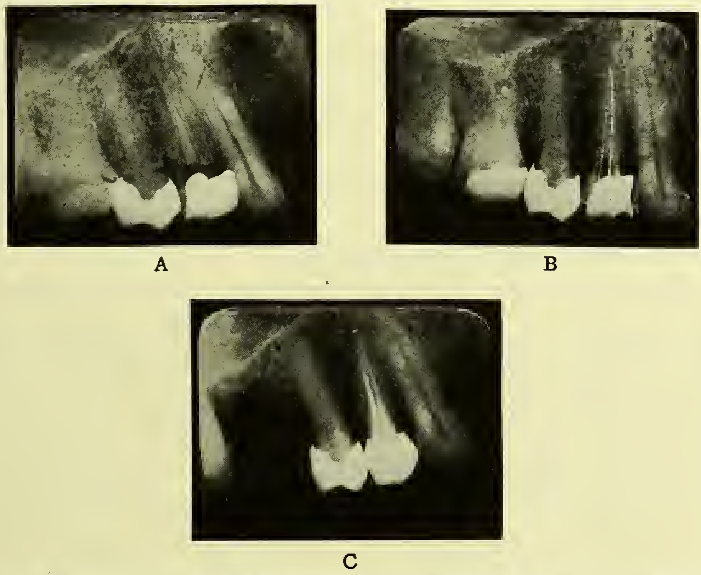


Fig. 985.—Series showing pulp canal surgery on upper first bicuspid with two canals. A, defective filling in crown and root; B, diagnostic wires in position; C, canals filled.

As diagnostic wires, old smooth broaches may be cut to convenient length, and used, or strands of small braided picture wire may be substituted. Diagnostic wires are also supplied by the manufacturer for this purpose. Figs. 983, 984 and 985.

GAINING ENTRANCE

The following directions should be borne in mind constantly during the performance of the technical procedures:

1. *When a cavity is present,* make the approach to the pulp chamber through the cavity.

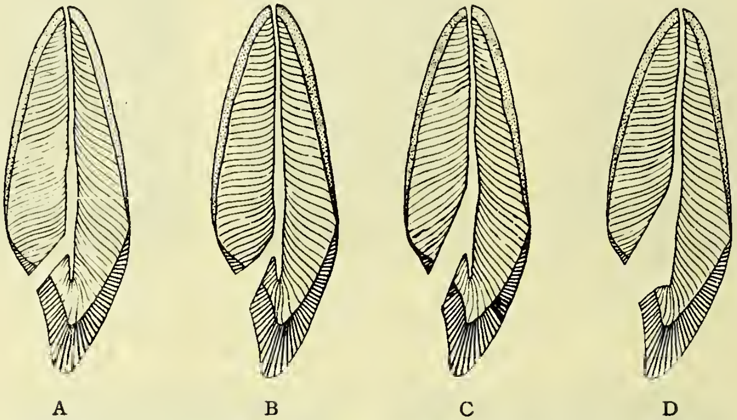


Fig. 986.—Showing the steps in entering, enlarging and opening the pulp chamber and canal through the lingual surface of an anterior tooth. A, entrance made into pulp chamber and enlarged; B, entrance further enlarged by drilling gingivally and incisally; C, approach to the canal enlarged and straightened for entrance of broach; D, horns of pulp removed by drilling incisally. Walls of pulp chamber and canal are now continuous.

2. *In sound teeth,* or teeth with perfect fillings, enter through the center of the lingual surface of incisors and cuspids, the mesial pit of bicuspids, and the central fossa of molars.

3. *Enlarge the opening,* whether through an already existing cavity or one artificially made, until convenient and thorough access to the pulp chamber and canals is obtained; at the same time, avoid mechanically weakening the tooth by too much cutting.

4. *Make the walls* of the cavity and pulp chamber continuous and smooth, though not necessarily parallel or on the same plane.

5. *Make the walls* of the pulp chamber and canals continuous and smooth. Fig. 986.

TECHNICAL PROCEDURES FOR OPENING PULP CHAMBERS

The **technic** for opening into pulp chambers in sound teeth is as follows:

1. *Perforate the enamel* with a number 1 round bur or a small spear-point drill, in the handpiece of the engine.

2. *Enlarge the opening* with a larger size bur or drill.

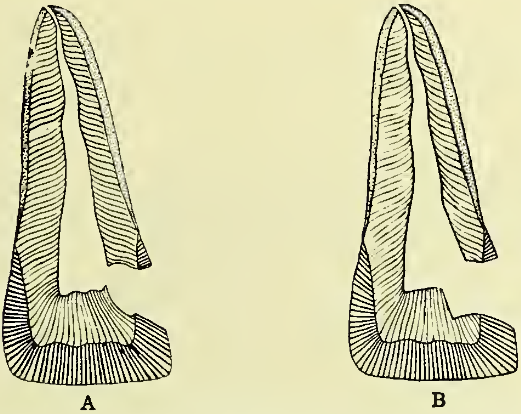


Fig. 987.—Opening through a proximal cavity on a central incisor. A shows the cavity of decay and pulp exposure with the difficulty of passing a broach to the apex. B shows the cavity properly opened, the horns of the pulp chamber removed, and the chamber and canal made continuous.

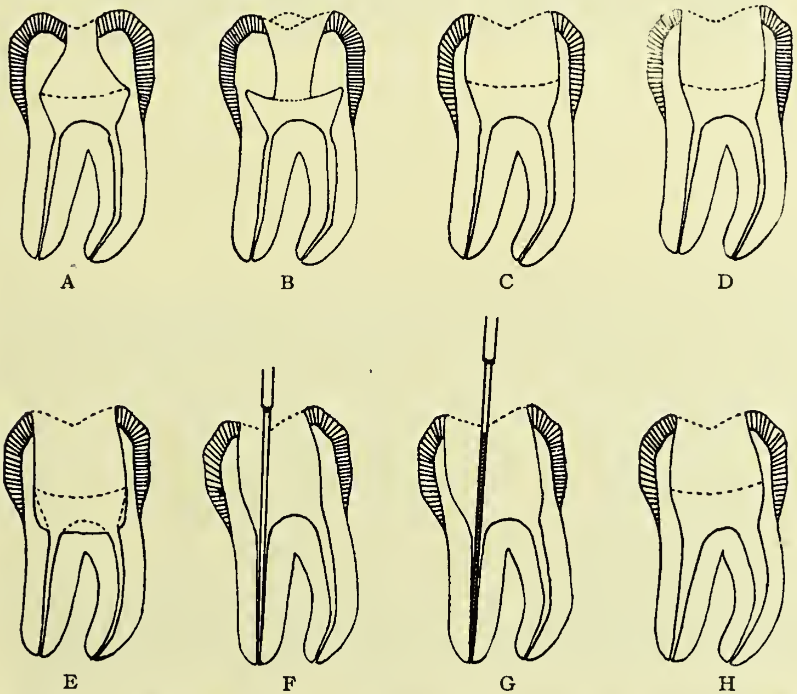


Fig. 988.—Showing the steps in opening the pulp chamber and canals through the occlusal surface of a lower molar. A, entrance too small; B, entrance enlarged, but still too small; C, cavity enlarged and horns of pulp chamber removed, but mesial and distal walls are incorrectly undercut; D, proper form; E, the floor of the pulp chamber has been incorrectly deepened with a bur, thus running the risk of drilling through the bifurcation of the roots and also obscuring the canal entrances. F, the cavity and pulp chamber have been properly prepared and the distal canal is being explored; G, the canals are being reamed and enlarged; H, canals enlarged and cavity, pulp chamber and canals are continuous and smooth.

3. *Perforate the dentin* gradually to the pulp chamber, alternating first with the smaller, and then with the larger size burs or drills, avoiding the danger of breakage by frequently withdrawing, and continuing in this manner until the pulp chamber is reached.

4. *Enlarge the opening* with the same instruments until convenient access is obtained, and then remove the entire wall of the pulp chamber, extending the cuttings out until the horns of the pulp chamber are included.

5. Make the walls of the cavity and pulp chamber continuous and smooth, but avoid cutting on the floor of the pulp chamber and obscuring the canal entrances. For this purpose use fissure bur number 57, 58 or 59.

6. Remove the contents of the pulp chamber and all debris with spoon excavator, 13–8–12 or 8–6–12 and the chip blower or air syringe.

The **technic** for opening through cavities of decay is herewith given:

1. *Establish the outline form*, remove all decay, and make the cavity slightly retentive.

2. *If the pulp is not exposed*, penetrate the dentin to the pulp chamber with the drills, or the round or fissure burs previously mentioned.

3. *Remove the wall* of the pulp chamber with a hoe excavator of proper size and angulation to suit the case; or a number 557, 558 or 559 denate fissure bur, extending the cuttings until the horns are fully included and the chamber is clearly exposed to view.

4. *In incisors and cuspids*, straighten the approach to the canal by extending the cavity in the lingual or gingival direction or both, depending on whether the entrance is being made from the lingual or proximal surface, with the dentate fissure burs.

5. *In upper molars*, straighten the approach to the mesio-buccal canal by extending the cavity with a fissure bur or cleoid excavator toward the mesio-buccal cusp, and enlarging the pulp chamber in the same direction by means of the same instruments.

6. *Make the walls of the cavity and pulp chamber* continuous and smooth, but do not use a bur on the floor of the chamber, for fear of clogging and obscuring the canal entrances.

7. *Remove all debris* with the spoon excavators and compressed air. Figs. 987 and 988.

ANATOMICAL CONSIDERATIONS

The following brief review of some important considerations with reference to the *Internal Anatomy* of the various teeth in their bearing on the technic of opening pulp chambers and canals is offered. Figures 989 to 996 are sections of natural teeth revealing the form of pulp chambers and canals. The anterior teeth, both upper and lower, usually have one root canal, which is continuous with the pulp chamber, and as a rule easily found after the approach has been straightened, as already described. The upper first bicuspids have, in the majority of instances, two canals, one buccal and one lingual, although in probably one-third of the cases, only one canal is present. The upper second and the lower bicuspids present, as a rule, a single canal. There is wide variation in the anatomy of the canals of upper first and second bicuspids. In some instances, they may open as separate canals and unite in the middle or apical third. In others, they may begin as a single obifpening, urcate

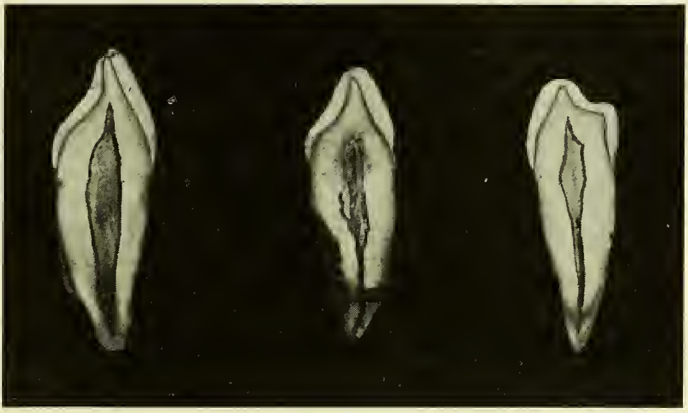


Fig. 989.

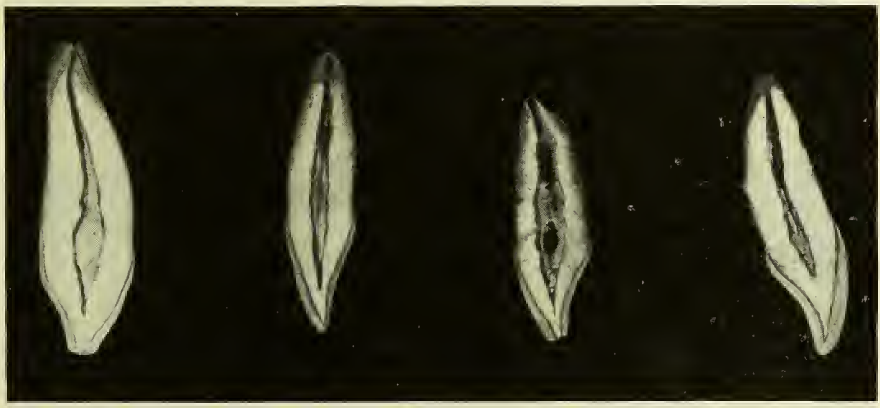


Fig. 990.

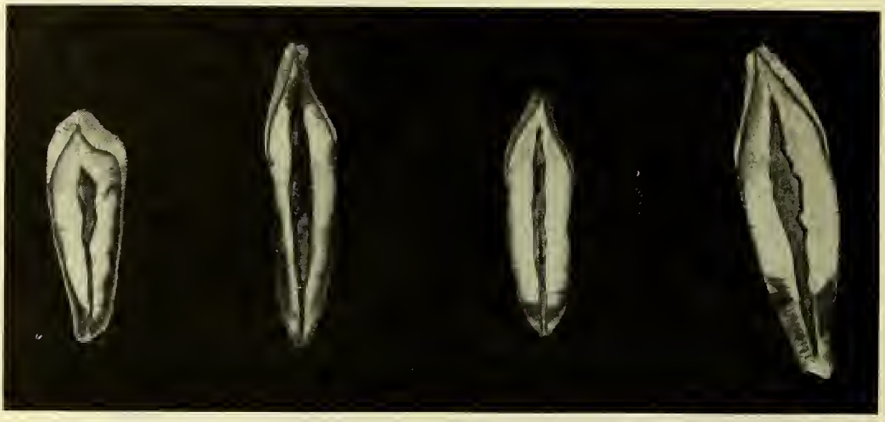


FIG. 991.

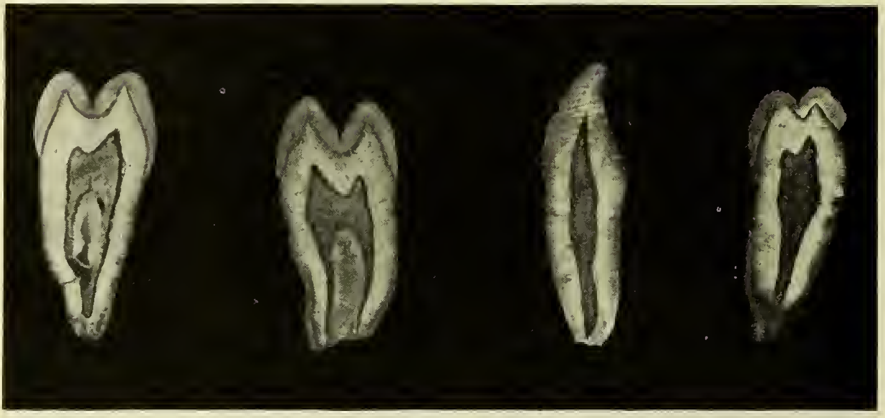


FIG. 992.

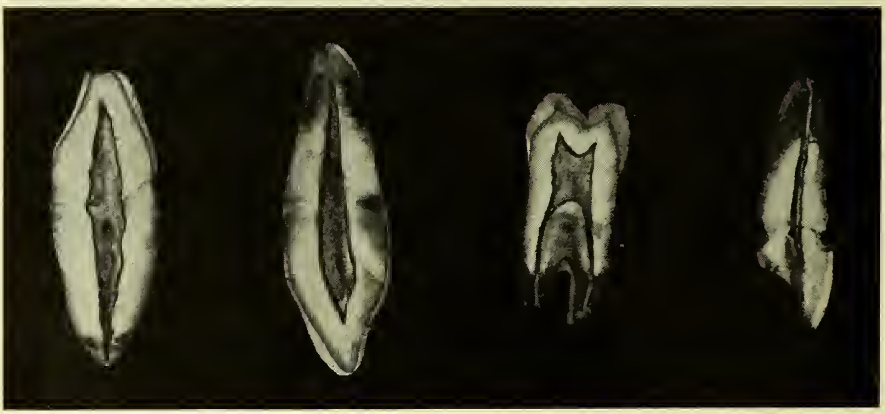


FIG. 993.

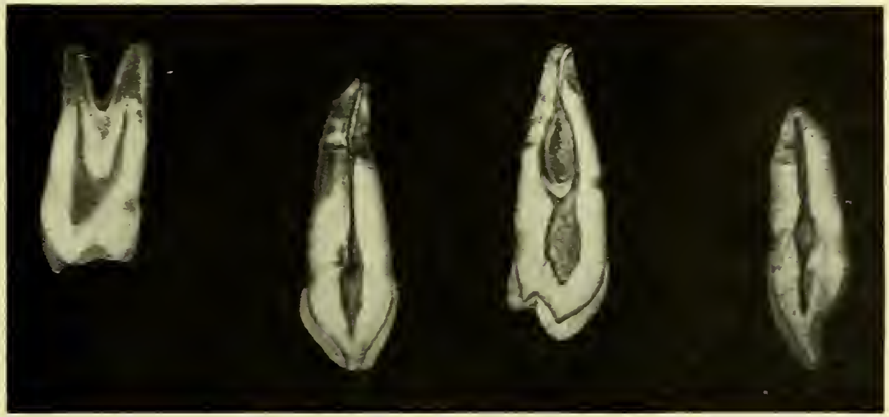


FIG. 994.

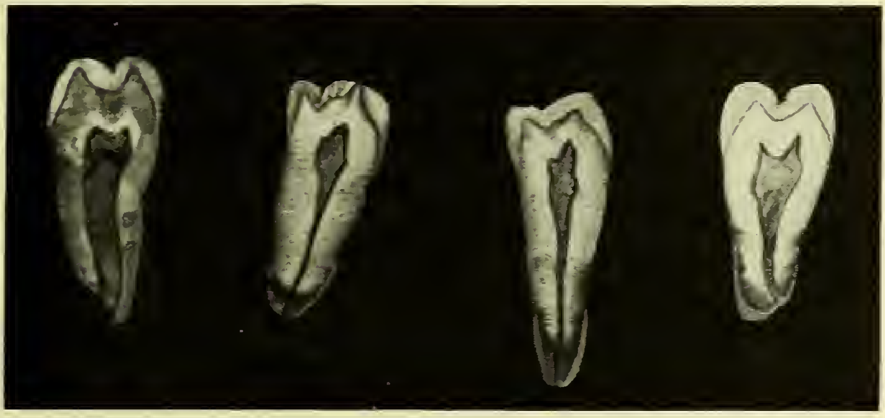


FIG. 995.

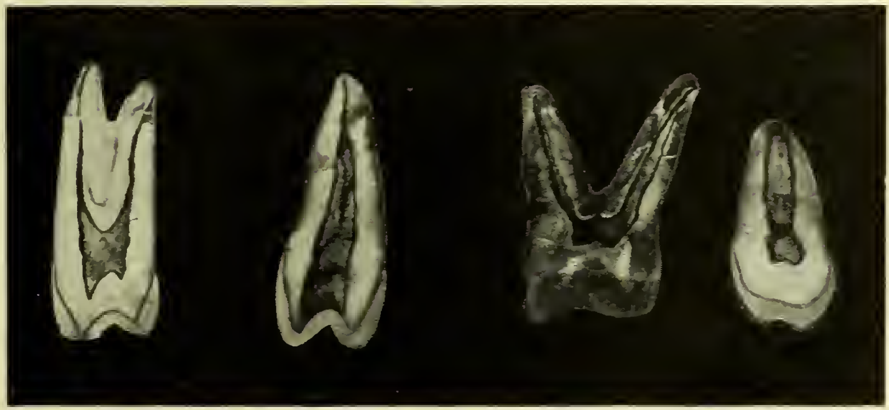


FIG. 996.

and remain separate for the remainder of their length. Occasionally, in the latter instances, after bifurcation, they may unite in the apical third. In the upper molars there usually are present three canals, a mesio-buccal, disto-buccal, and a lingual, their entrances forming a triangle (molar triangle) (Figure 997), while in the lower molars there are, as a rule, a mesio-buccal and a mesio-lingual canal, located in the mesial root, and a distal canal situated in the distal root, their entrances also forming a triangle. The possibility, however, of the existence of additional canals in molars as well as in other teeth always should be borne in mind. The canals in the lower bicuspids are more or less continuous with the pulp chambers, while those in the upper bicuspids and the upper and lower molars are usually separate and distinct from the chamber, opening from its floor with more or less constricted orifices. Owing to the presence of these constrictions, the small size of the buccal canals in the upper molars and the mesial canals in the lowers, and to secondary dentin deposits, difficulty frequently is experienced in locating their entrances and following them with instruments to their termination. The probability of minute accessory and lateral canals, impossible of opening is always present. Fig. 998.

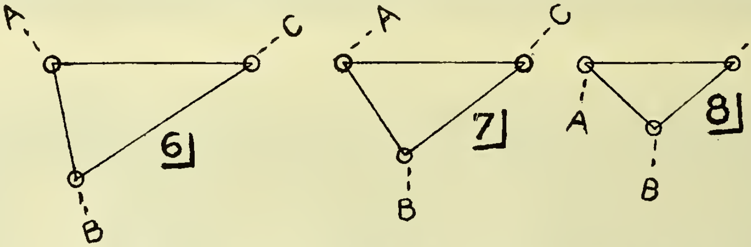


FIG. 997.—The molar triangle in the upper first, second and third molars respectively, of the right side. A, mesio-buccal canal; B, disto-buccal canal; C, lingual canal.

TECHNICAL PROCEDURES FOR OPENING CANALS

The **technic** for opening and removing the contents of the canals is outlined as follows:

1. *Locate the entrance* and explore the canals as far as possible with a small, round, smooth broach or canal probe. The Rhein root pick, the Twentieth Century pathfinder and the Kerr root probe (Figs. 999 and 1000), are all valuable instruments for this purpose.

2. *Enlarge the orifice* of the canals with a Kerr tapered canal cleanser or a Donaldson or S. S. W. canal cleanser (Figs. 1001 and 1002).

3. Make the walls of the pulp chamber and canals continuous, with the same instruments.

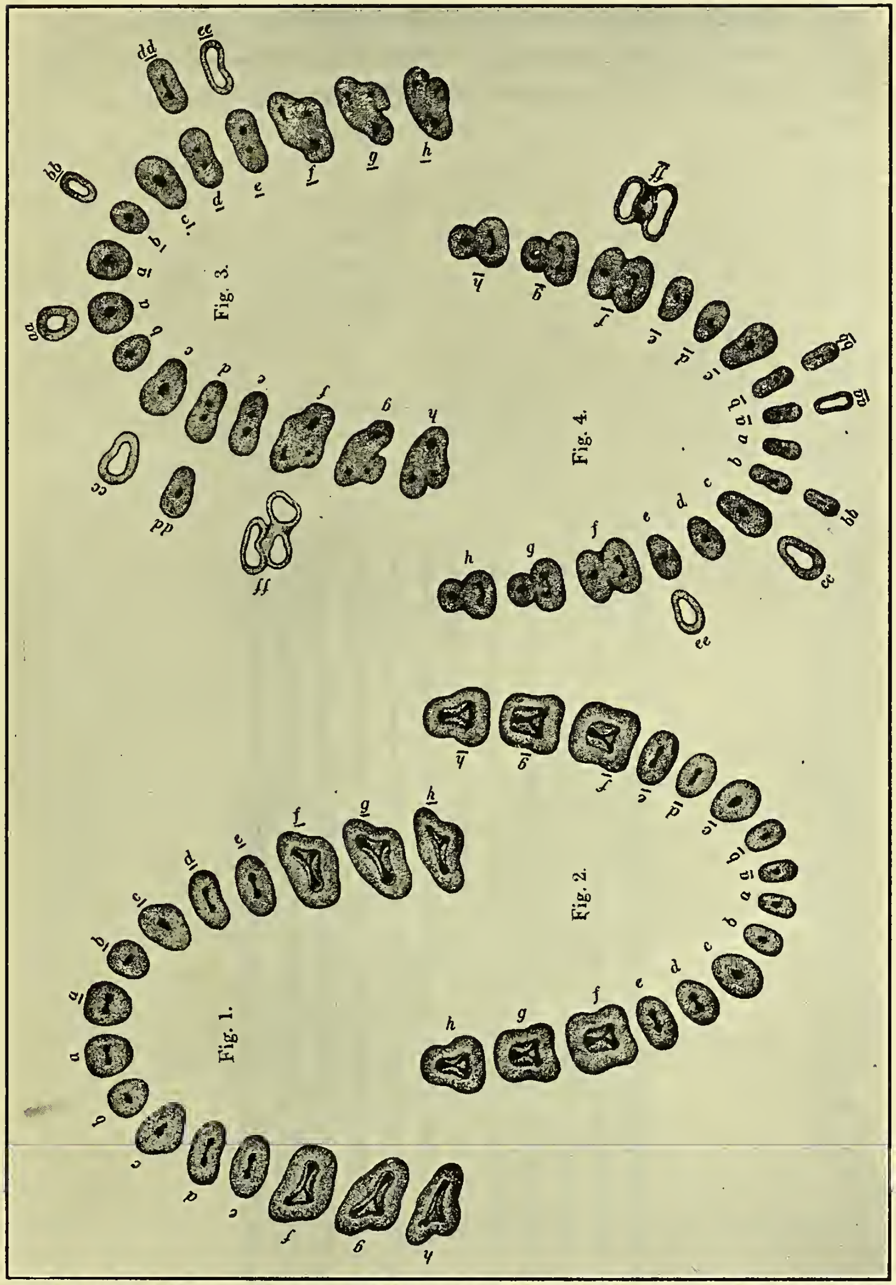


FIG. 998.—Figs. 1 and 2 represent the upper and lower teeth respectively in transverse section through the pulp chambers and canal entrances. Figs. 3 and 4 represent transverse sections of the roots of the upper and lower teeth after divergence from the pulp chambers, but before bifurcation of roots of posterior teeth has occurred. (From V. Carabelli's Anatomie des Mundes.)

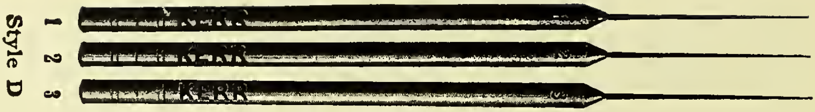


FIG. 999.—Pulp canal probes.

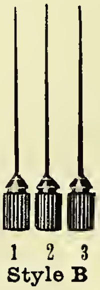


FIG. 1000.—Pulp canal probes.

FIG. 1001.—Canal cleansers or barbed broaches.

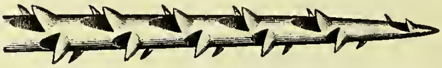


FIG. 1002.—Enlarged barbed broach.

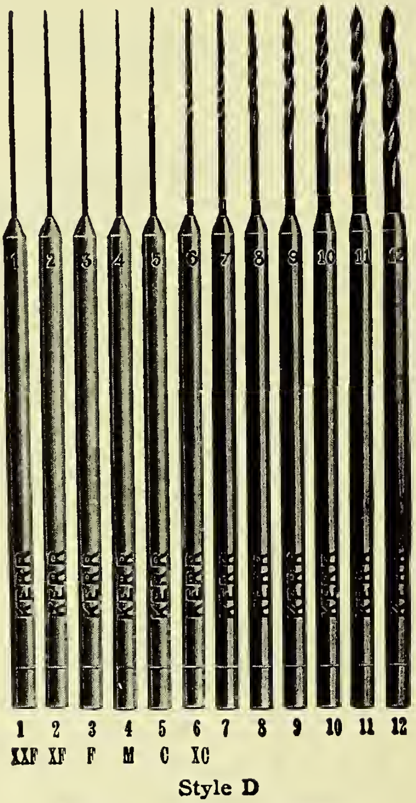


FIG. 1003.—Pulp canal reamers.

4. Pass a small canal cleanser to the apex, or until it binds, withdraw slightly, give it a half turn and then remove from the canal, bringing away as much of the pulp tissue as possible. Continue this, using larger and larger sizes, as the canal will permit, broaching or filing the sides of the canals, and gradually enlarging them. Carry the broach just to the dentino-cemental junction at the apex, and no further. The passage of the broach through the apical foramen will produce irritation in the tissues of the apical space, and consequently should be avoided.

TECHNIC FOR SMALL CANALS AND DIFFICULT CASES

In small canals, where entrance with the pathfinder and the barbed canal cleanser is difficult, change to a spiral broach reamer, a twist broach, a Kerr root file (Figs. 1003 to 1008), or Twentieth Century rat-tail file. Start with the smallest size, carefully boring in and withdrawing in a direction which will tend to straighten the canal, gradually changing to larger and larger sizes, until the canal is thoroughly opened.

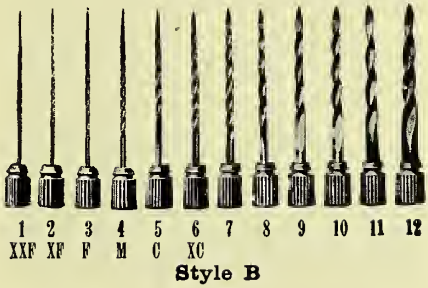


FIG. 1004.—Pulp canal reamers.

In difficult cases a 40% solution of sulfuric acid, or hydrochloric acid, carried into the canal on the broach, will, by uniting chemically with the organic matter and the calcium salts of the dentin, dissolve the organic matter, soften the walls of the canals and render the work easier. The action of these acids should be neutralized on completion of the operation with a saturated solution of sodium bicarbonate or with sodium dioxid or sodium-potassium alloy. These latter preparations also produce effervescence, which assists in removal of the debris from the canal. For enlargement of the canals, sodium-potassium and sodium dioxid also may be used. These agents also destroy by oxida-

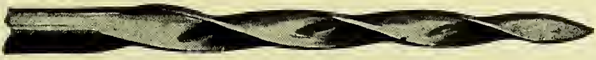


FIG. 1005.—Canal reamer enlarged.

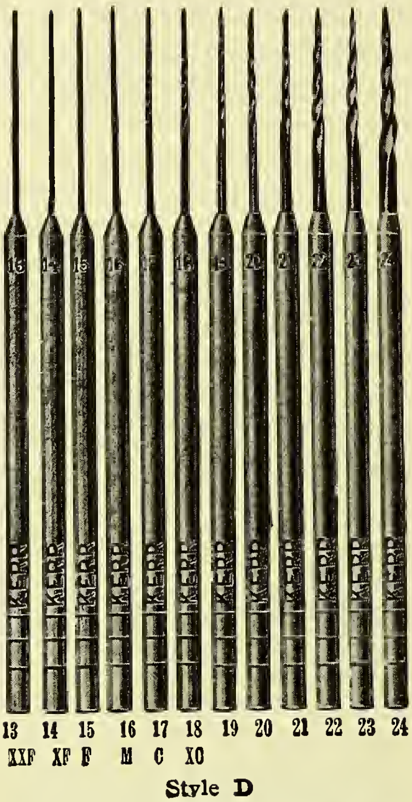


FIG. 1006.—Tapered pulp canal reamers.

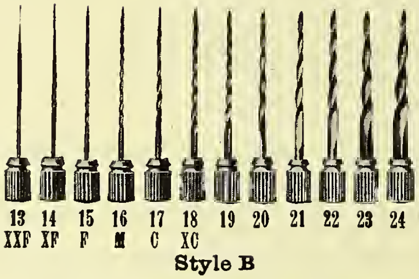


FIG. 1007.—Tapered pulp canal reamers

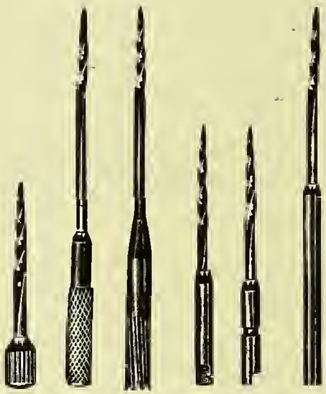


FIG. 1008.—Pulp canal reamers for hand and engine.

tion the organic matter, soften the canal walls and act as bleaching agents to discolored dentin.

Remove all debris, apply the diagnostic wire and obtain a radiogram. If the dentino-cemental junction is not reached, as indicated by the radiogram, continue the procedures, and repeat the radiographic exposures until the canal is satisfactorily opened and enlarged.

After the proper medicinal treatment has been given, depending on the conditions present, as already described, the canals are ready for ionization, drying and filling. For illustrations showing progressive technic in opening pulp chambers and canals see Figs. 986 to 988 inclusive.

METHODS OF FILLING CANALS

It is necessary that the canals to be filled have been thoroughly opened and treated under aseptic precautions, the saliva excluded throughout the course of treatments, all debris, and remaining decomposable material and infection removed, absolute dryness accomplished and adequate access for filling obtained. Ionization should be resorted to immediately before filling.

Microscopic Examination.—In doubtful cases, a smear should be obtained from the canal and bacteriologic examination made with the microscope. Treatments should be continued until the microscope reveals absence of infection. The technic of this procedure is, briefly, as follows:

1. Under aseptic precautions, smear the dressing from the root canal on to the surface of a clean microscopic slide.
2. Dry the smear thus obtained, by exposure to the air.
3. Fix by passing rapidly three times through a flame.
4. Stain for three to five minutes in Loeffler's alkaline solution of methylene blue.
5. Wash off excess stain.
6. Invert a cover glass on the stained slide with the film side down and then blot dry.
7. Place a drop of cedar oil over the film and examine with an oil immersion lens (1.9 or 1/12 inch).

If preferred, the dentist may obtain the cooperation of a bacteriologic laboratory in obtaining and examining smears.

Drying Canals.—Dry thoroughly with repeated applications of sterile absorbent paper points, made by the manufacturers for this purpose. Then force in a current of hot air from the heated bulb of the chip blower, or use some of the various forms of root-canal driers, until absolute dryness is accomplished, when, after ionization, the canals are ready to fill. Fig. 1009.

Requisites of a Canal Filling Material.—It should be:

First—Non-irritant to the tissues of the apical space.

Second.—Indestructible in the fluids entering at the apex, or through the pulp chamber (in case of leaky fillings).

Third.—Easy of introduction.

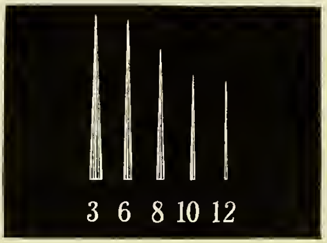


FIG. 1009.—Guttapercha canal points.

Fourth—Aseptic, not necessarily antiseptic.

Fifth.—Colorless.

Sixth.—Free as possible from shrinkage.

Seventh.—Capable of perfectly sealing the inner orifices of the dentinal tubules, accessory and lateral canals.

Eighth—Easy of removal (in case of trouble arising later).

Ninth.—It should be negative to the penetration of the X-ray.

GENERAL INSTRUCTIONS FOR FILLING CANALS

Endeavor always: (1) to completely seal the apical foramen to the dentino-cemental junction; (2) to avoid forcing the material through; and (3) to so adapt the material to the walls of the canal that all air will be excluded, and the canal for its entire length be hermetically sealed. The radiograph should always be used in "checking up" root-canal work at its termination. If the canal has not been filled to the dentino-cemental junction, a space will be left for seepage of moisture and possible infection later. Figs. 1010 and 1011. In case this has not been accomplished as revealed by the roentgenogram, an attempt may often be made at once to further condense the filling material by heating with warm air and the use of warm root pluggers, before the material has fully hardened. If this fails, the material should be removed and a second filling placed. In some instances, the roentgenogram will show that the soft material has been forced through the apex into the apical space, thus encapsulating the root end. Encapsulated root apices in

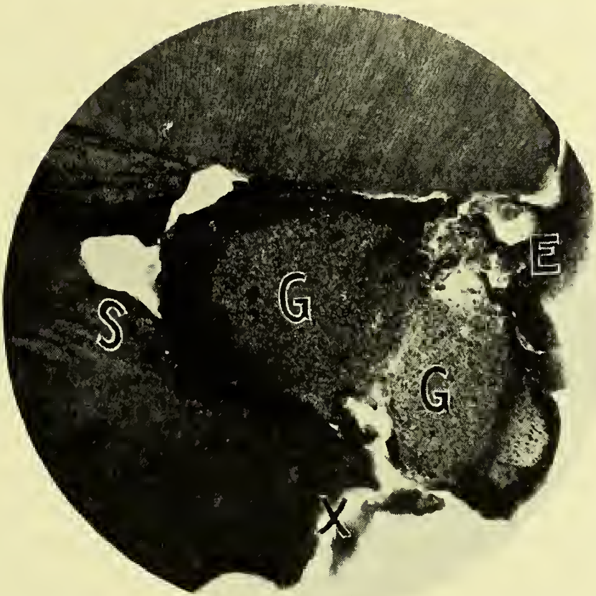


FIG. 1010.—Apex of distal root of a molar. G, canal points extending through apical foramen; E, pericementum showing round cell infiltration; S, secondary dentin; X, absorption of root end. (Courtesy of Dr. O. H. Moen and "Journal of American Dental Association.")

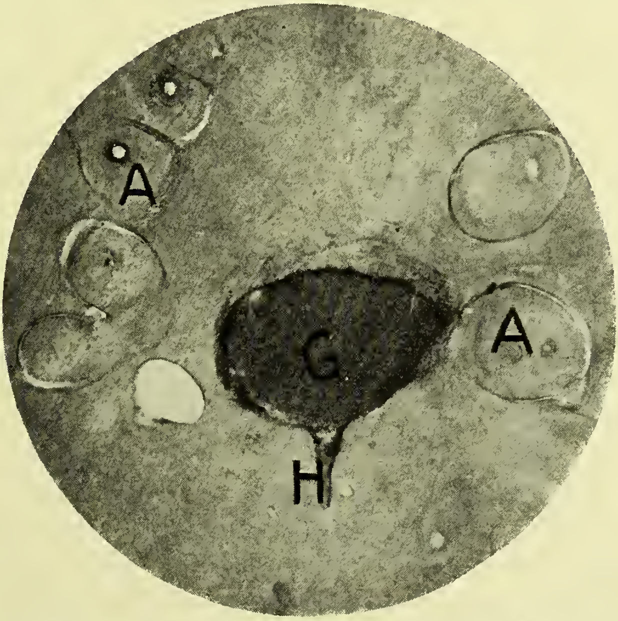


FIG. 1011.—Cross section of a root three mm. from apex. A, accessory canals nearly closed by secondary dentin; H, hypertrophic degenerating tissue in an accessory canal leaving the main canal; G, guttapercha canal filling, good technic. (Courtesy of Dr. O. H. Moen and "Journal of American Dental Association.")

the majority of cases give no trouble, provided the material forced through is of limited amount and is of a bland, unirritating nature, such as chloropercha. Slight encapsulation of the apex with chloropercha is far preferable to incomplete filling of the canal, especially in cases of previous slight absorption of periapical tissues. In cases where the radiogram reveals its presence, it should be given no special clinical significance, unless it subsequently causes disturbance. In the majority of cases, tenderness and evidences of slight irritation (traumatic pericementitis) may follow for a few days, but usually quickly subside. In rare cases of apparently permanent injury, apicoectomy or extraction is indicated. In no instance should guttapercha or other root canal points be forced through apical foramina, since they will likely produce permanent injury.

Historical.—Reference to the works of Fouchard (1728), Bourdet (1757), Hunter (1778) and other early writers informs us that it was the practice at these early dates to attempt to destroy the "nerves" of teeth giving trouble, with the actual cautery or with caustics. These authors also mention the oil of cloves and other medicinal agents placed in the canal on cotton wool for the treatment and filling of root canals. In 1824 Edward Hudson, a dentist of Philadelphia, rendered a bill to a patient for filling the root canals of a tooth with gold. The use of gold, lead and tin was used for this purpose by American dentists in the early part of the nineteenth century. Hill's stopping, introduced in 1849 was later used as a canal filling material, which was then followed in 1872 by chloropercha alone and later superseded by a combination of chloropercha and guttapercha points. Oxychlorid of zinc cement, introduced in 1859, was also much used for the same purpose, as well as many other substances, including cotton, silk, asbestos, wood points, pastes and others, too numerous to mention. In the Dental Items of Interest, Vol. 23, June, 1901, pp. 458, Weston A. Price first advocated the use of the X-ray in conjunction with root therapy procedures. However, the first definitely organized technic for root canal work supported by the roentgenograph was described by Doctor M. L. Rhein in Dental Items of Interest, Vol. 30, November 1908, page 833.

Great improvements have been made in the materials and the technic of insertion during the past decade. As a result, with an increased knowledge and improved facilities, much better and surer results may now, with proper care be accomplished. Efforts are still in progress to further improve technical procedures and they are meeting with much success, as a perusal of the modern literature on the subject will indicate.

As a result, unscientific statements, as made by some in the past, that all pulpless teeth should be extracted for fear of the possibility of subsequent complications, will be met with contempt by well-informed, modern-minded professional men.

As previously mentioned in an earlier chapter, the profession is still in search of the ideal filling material for insertion into prepared cavities of the crowns of teeth. So also is it still endeavoring to find the ideal pulp canal filling material and the technic of its insertion. At the present time, many technics are being advocated and it would be impossible to adequately describe them within the space here allotted. However, most of them are mentioned and the more important ones are given due consideration. The student is referred to the bibliography appended at the end of this chapter for additional information.

The early methods of treating and filling pulp canals practised by Drs. G. V. Black, John R. Callahan, John P. Buckley and others are herewith briefly presented in the following pages. *The technical procedures and instrumentation of the author of this book have been described in the preceding pages* (*pages* 850 to 882). *The therapeutic methods advocated by the author are given on pages* 893 to 908 *inclusive.*

METHOD OF G. V. BLACK

This method is applicable only in special cases of very large canals or foramina which are easily accessible to instrumentation.

1. *Measure the diameter of the apical foramen.* Pass a small, smooth broach or canal plugger, to the apex. If it passes through, change to a size larger, or two sizes larger, continuing until one is found which will pass just short of the apical foramen. The diameter of the instrument will thus correspond to the diameter of the canal at the apex.

2. *Measure the length of the canal.* Pass a small, smooth broach or canal plugger of suitable size to the apical foramen. A small piece of cardboard, rubber dam, or a "stop," encircling the shaft of the broach is moved until it is in contact with the crown of the tooth, when, the broach being withdrawn, a measurement of the length of the tooth is seen, and a guide as to the length of the canal is obtained. (Fig. 1012.) Or pass to the foramen a small sterile diagnostic wire of suitable size, bend the outer end over the margins of the cavity or onto the floor of the pulp chamber. Now seal into place with guttapercha and take a radiogram. By later comparing the removed diagnostic wire with the radiogram, the length of the root may be determined.

3. *Select a tapering guttapercha cone,* approximating the size of the canal, and cut off its end, until it is the size of the apex as previously determined.

4. Cut off a section about three or four millimeters in length, which will be utilized for filling the apical portion. Also cut the rest of the cone into small sections for filling the balance of the canal.

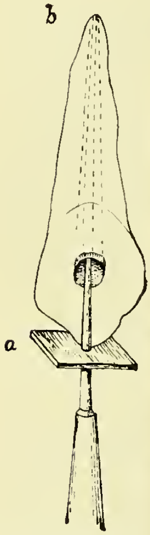


Fig. 1012.—Measuring the length and diameter of the canal with a canal plugger. a, "stop"; b, root apex.

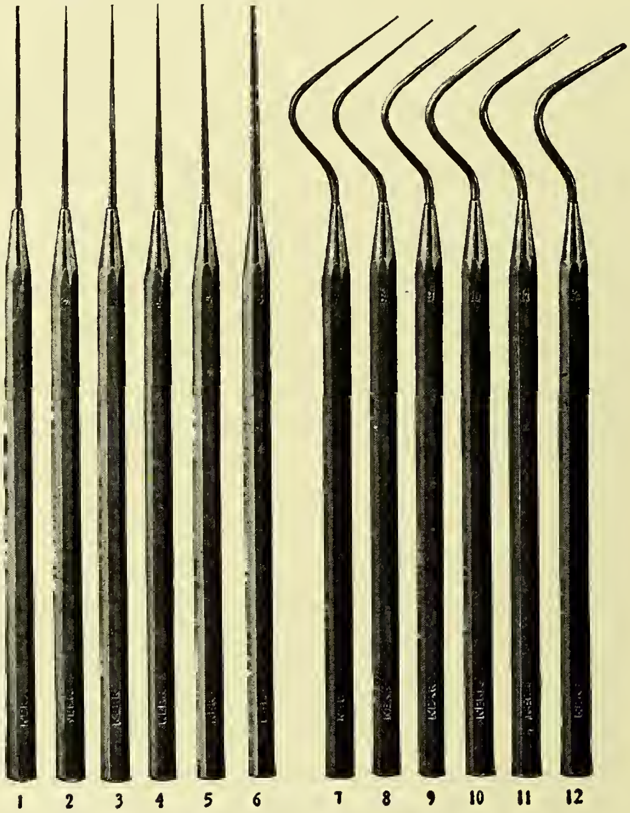


Fig. 1013.—Pulp canal pluggers.

5. *Select an absorbent point,* dip it in eucalyptol and freely moisten the canal. Avoid too much pressure on account of the tendency to form a piston and force the solution through the apex. Remove all excess of eucalyptol with an absorbent point, leaving the wall slightly moistened with eucalyptol.

6. *Catch up the smallest section* of the guttapercha cone on the end of a warmed root canal plugger (Fig. 1013), dip it in eucalyptol, remove the excess, carefully carry it to place and tamp to position, withdrawing the plugger, when the apical portion is filled.

7. *Continue the procedure* with the next largest pieces in order, carefully packing to position, and warming the largest pieces, until the canal is filled; then seal the pulpal opening with a warm plugger or burnisher.

8. *Fill the pulp chamber* with oxyphosphate of zinc cement. Perform all procedures under aseptic precautions.

METHOD OF JOHN R. CALLAHAN

The profession is greatly indebted to Doctor Callahan for his extensive researches in pulp canal therapy and filling. This work was reported in the Dental Cosmos, The Journal of the American Dental Association, The Dental Summary and extensively figures in other publications from 1914 to 1916. Many of the more modern methods are quite largely modifications of his technic, which is now briefly presented.

After treating the canals and burning out the organic matter from the tubules and accessory canals with 40% sulfuric acid, as advocated by Callahan in 1893, followed by a saturated solution of sodium bicarbonate, and drying thoroughly, pump the canal full of chloroform and resin mixture (resin twelve grains, chloroform, three drams). This mixture, of the consistency of machine oil, slightly permeates and seals the orifices of the dentinal tubules and accessory canals. Then take a guttapercha point of suitable size, insert into the canal while the resin is still liquid, and by a pumping motion frequently repeated (forty to sixty times), dissolve the point in the solution until the canal is thoroughly filled, thus further forcing the resin solution into the accessory canals and tubules, and filling the main portion of the canal with the guttapercha, which is slowly transformed into chloropercha by gradually becoming dissolved in the solution. A modification of the Callahan method is to pump the canal full of chloropercha after insertion of the chloroform and resin mixture, and then insert a guttapercha point of suitable size. Also if the apical foramen be large, it may first be filled by tamping in place a small section of guttapercha point, to avoid forcing resin and chloropercha through the opening.

Additional materials for filling canals, advocated from time to time, to be used either alone or in combination with points of guttapercha, silver, lead or gold are: chloropercha; oxychlorid of zinc cement; copper amalgam; paraffin, alone or mixed with salol, aristol, or iodoform; salol; Prinz' root canal filling material (composed principally of base plate gutta-percha and paraffin oil); and Euca-percha.

METHOD OF JOHN P. BUCKLEY

1. Moisten the canal with eucalyptol.

2. Dip an absorbent point into softened euca-percha compound (white base plate guttapercha dissolved in eucalyptol) and pump the canal as full as possible, avoiding forcing the material through the apex.

3. Force in on a root canal plugger or smooth broach, squared on the end, a section of a guttapercha cone, as large as the canal will accommodate and seal the entrance to the canal with a warm canal plugger or burnisher.

4. Fill the pulp chamber with cement.

Doctor Buckley[16] has more recently introduced a material, which he calls Dentinoid, as a substitute for euca-percha. This material, in the form of a powder is radiopaque and is a mixture of calcium phosphate, barium sulphate, thymol, thymol iodid, orthoform and resin. In using, it is mixed with alcohol into a thin paste, and is carried into the previously treated canals until full, to seal the tubules and accessory canals. Then a previously selected, specially prepared lead point is forced into the dentinoid, thus filling the canal. Guttapercha points may be used instead of the lead points. Buckley claims permanently antiseptic properties for the dentinoid, which, therapeutically, is not in keeping with modern ideas in regard to the desirable qualifications of a canal filling material. He also recommends the material for use as a pulp protector.

METHOD OF U. GARFIELD RICKERT

Doctor Rickert[17] in 1927 introduced a plastic material for filling canals which he claims is radiopaque, nonshrinkable, temporarily germicidal and permanently adhesive to the walls of the canals. The method of its use is somewhat similar to that recommended for introduction of other types of plastics into root canals. Doctor Rickert states that the composition of the mass, when set is

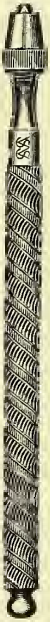


FIG. 1014.—Broach holder.

Silver	24.74%
Zinc iodid	34.00%
Dithymol diodid	10.55%
Oleoresins	30.72%

METHOD OF HERMAN PRINZ

Doctor Prinz's method is fully described in his text-book entitled "Diseases of the Soft Structures of the Teeth and Their Treatment." He stresses the importance of thorough dehydration of the canal with heat and the infiltration of the dentinal tubuli with a rosin solution. His formula for the latter differs from that of Callahan and consists of

Rosin	15 grains (1.00 gm.)
Sodium bicarbonate	4 grains (0.25 gm.)
Aceton	2 ounces (64.00 cc.)

The rosin solution is pumped into the canal on an absorbent paper canal point and the aceton is then evaporated with heat, thus leaving a thin film of rosin to seal the ends of the tubules. The walls of the rosin coated root canals are then covered with a thin layer of a special "guttapercha paste" of the following formula:

Guttapercha base plate	½ ounce
Pure paraffin oil	½ ounce

The guttapercha is dissolved in the paraffin oil by heat. Dr. Prinz claims that this combination does not shrink, but clings to the canal walls when carried in on a heated smooth broach or canal plugger. He emphasizes the importance of using only a small amount of the paste. After measuring the length and diameter of the canal as described in the Black Method and the making of a radiogram, the canal is now filled with ⅛ inch sections of guttapercha cones or points of suitable size.

METHOD OF EDGAR D. COOLIDGE

Doctor Collidge[18] stresses the importance of a thorough and systematic placing and use of the instruments and accessories on the operating tray, an aseptic technic, of obtaining proper measurement of the length of the canal and diameter of the apical foramen and of filling just to the dentino-cemental junction. The length of the canal is checked up with a diagnostic wire placed in position and radiographed, while the diameter of the foramen is measured with canal pluggers, following the Black Method. After thorough drying, the canal is moistened with eucalyptol or rosin solution and a very small amount of chloropercha is carried in to line the canal walls. Following this, the canals are filled by tamping to place proper size pieces of guttapercha points, 3 millimeters long, with warmed root canal pluggers, after the "sectional" method. For insertion of the first section, Doctor Coolidge selects one, 3 millimeters long and of proper diameter to fill the apical end. This is carried to place with a plugger which will pass 3 millimeters short of the dentino-cemental junction so that, when the section is tamped to place, assurance can be had that it has been carried to the desired position. The remainder of the canal is then thoroughly filled with small sections.

The profession is deeply indebted to Dr. Coolidge for the outstanding work he is doing in helping to solve the many problems confronting it in the field of root canal therapy and surgery. Figs. 1015, 1016 and 1017.

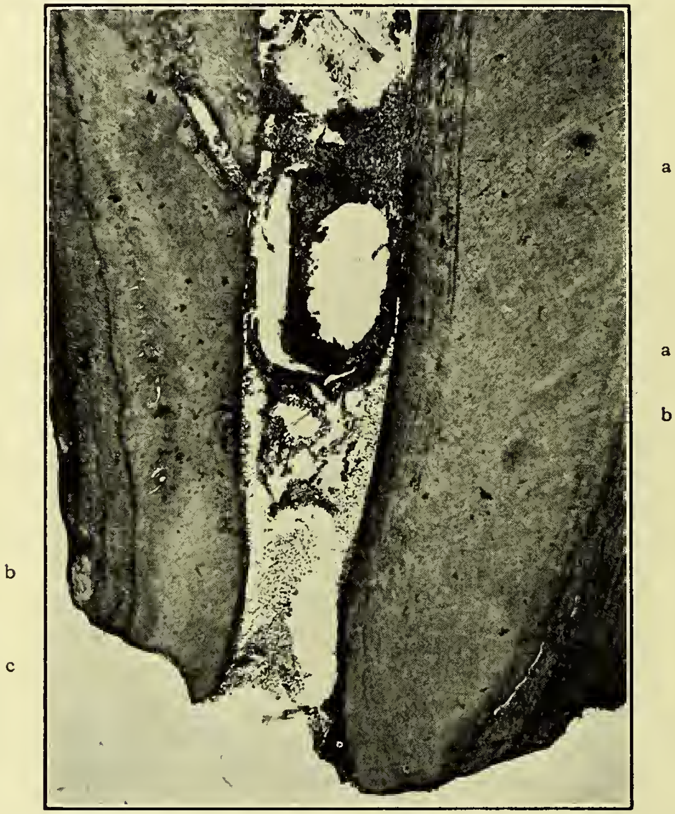


FIG. 1015.—Section of a root end showing poor filling technic and infection. a, guttapercha canal filling partly lost while sectioning; b, leucocytes (pus); c, resorption at apex. (Courtesy of Dr. E. D. Coolidge and "Journal of American Dental Association.")

METHOD OF J. R. BLANEY

The technic of Doctor Blaney is essentially the same as that used by Doctor Coolidge and is fully described by him in the Journal of the American Dental Association, Vol. XV, No. 2, Feb., 1928, page 203. He uses the so-called "sectional method," with sections of guttapercha points 3 millimeters in length. He stresses (1) the importance of the material approaching closely the remaining vital pulp stump at the apical opening without exerting pressure on the soft tissue, and (2) the complete filling and hermetical sealing of the entire length of the canal.

METHOD OF EDOUARD M. HALL

Doctor Hall's method is described by him in the Journal of the American Dental Association, Vol. XVII, No. 1, Jan. 1930, p. 3. Some of the essential features of his technic are different from those previously described. Lack of space prohibits a full presentation here. Briefly, however, Doctor Hall attempts to fill to the dentino-cemental junction, approximately 1 millimeter from the apex and stresses the undesirability of root end encapsulation. He makes no attempt to prepare the canal in conical shape, but uses a technic and instruments designed to so enlarge the apical third that the entire canal will be approximately of the same diameter, the so-called "choke-bore," in which the apical region will present a definitely choked or constricted ending at the dentino-cemental

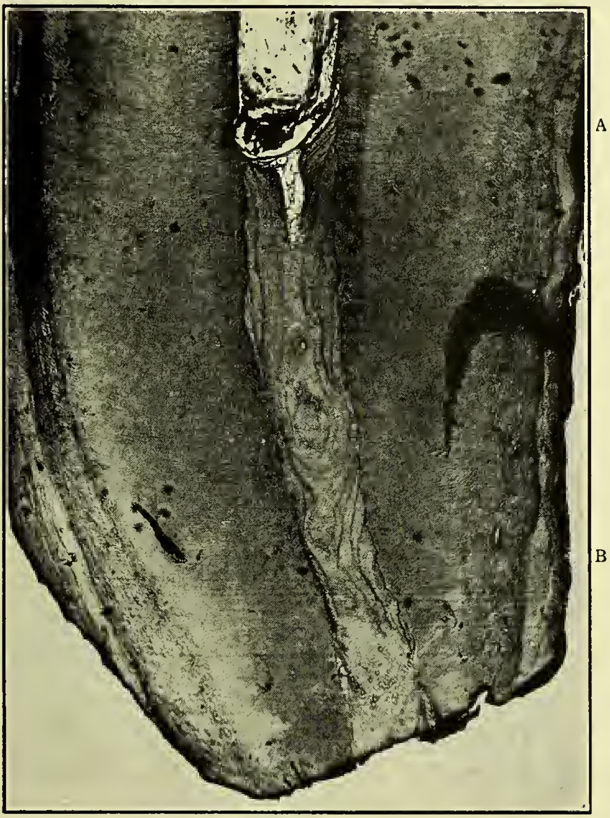


Fig. 1016.—Section of root end showing presence of bone-like substance in pulp canal beyond a guttapercha canal filling. A, guttapercha; B, bone-like formation. (Courtesy of Dr. E. D. Coolidge and "Journal of American Dental Association.")

junction, beyond which a guttapercha cone will not pass. He stresses the importance of an aseptic technic, decries the application of irritant caustics, and does not advocate the use of the "sectional method" or of semi-liquid or pasty substances, such as chloropercha, etc.

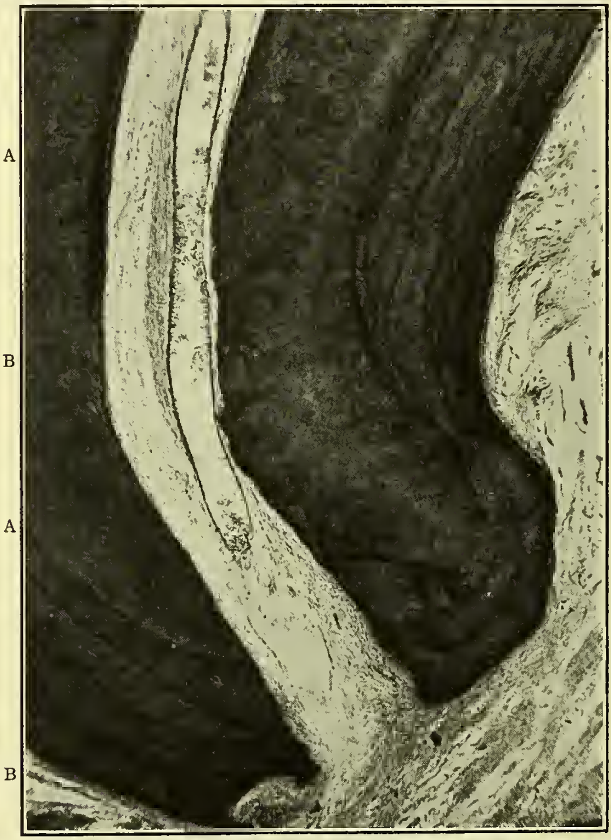


Fig. 1017.—Section of a root end showing enlarged blood vessel and resorption. A, blood vessel; B, resorption of canal wall opposite blood vessel and at apex. (Courtesy of Dr. E. D. Coolidge and "Journal of American Dental Association.")

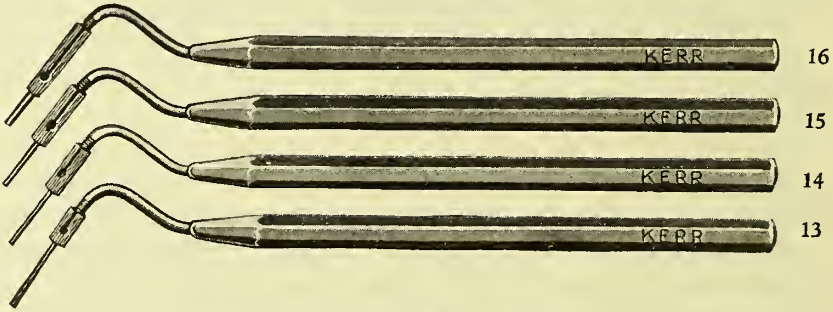


Fig. 1018.—Hall measurement control pluggers.

After preparation of the canal, a guttapercha cone of proper size is selected and fitted the full length of the canal. Its small end is cut off so that it fits as nearly as possible the apical third with its constricted orifice, and its large end is cut so that it extends to a previously determined landmark in the pulp chamber. Roentgenograms and a properly trimmed and fitted diagnostic wire will assist in obtaining this "test cone." Several other guttapercha cones are made in the same manner and placed ready for use. A few drops of chloroform-rosin solution are now placed at the entrance to the canal, one of the prepared guttapercha cones is placed on a special plugger of Doctor Hall's design, carrying a threaded sleeve nut, acting as a measuring device, quickly carried into the canal and, by a pumping motion, the chloroform-rosin solution is carried in and the walls of the canal are lubricated. Fig 1018. The chloroform in the solution dissolves and absorbs some of the guttapercha from the surface of the point. The guttapercha point is now withdrawn, excess chloropercha-rosin solution is absorbed on an absorbent paper point, when the guttapercha point is heated and again forced to place. Now, with a small guttapercha "spreader" of Doctor Hall's design. which is forced deeply in between the wall of the canal and the guttapercha point, lateral pressure is brought to bear against the guttapercha, to force it closely against the opposite wall of the canal. Fig. 1019. As soon as this is accomplished, another guttapercha point is carried into place and plugged with suitable root canal pluggers. In very large canals a third one may be needed. The chief advantages the originator claims for this method are the minimum amount of semiliquid substance required, the elimination of the danger of forcing it or guttapercha points through the apical foramen, and the use of lateral pressure to produce more perfect condensation, adaptation and filling of the canal throughout its length.

METHOD OF CARL J. GROVE

Doctor Grove has designed an ingenious set of charts, instruments and gold cones or inlays for opening and filling canals. The gold cones are standardized or gaged to the apical third of the reamer used in shaping the canal. The root "inlay" is the same diameter as the reamer. Average measurements of the length and diameter of root canals are presented on a special chart, with the aid of which the operator may determine the approximate length of the canal to be operated upon. On the chart are also indicated the size of reamers indicated for individual cases. A shoulder is drilled into the wall of the upper entrance to the canal, into which a special holder for carrying broaches, reamers and gold cones may rest. The holder is provided with a vernier and millimeter scale for making the desired measurements. By inserting the instruments used in preparing the canal and the gold cone for filling in the same relative positions in the holder, as indicated on the millimeter scale, it is claimed by Doctor Grove that, assisted by roentgenograms, it is always possible to fill just to the dentino-cemental junction. Fig. 1020.

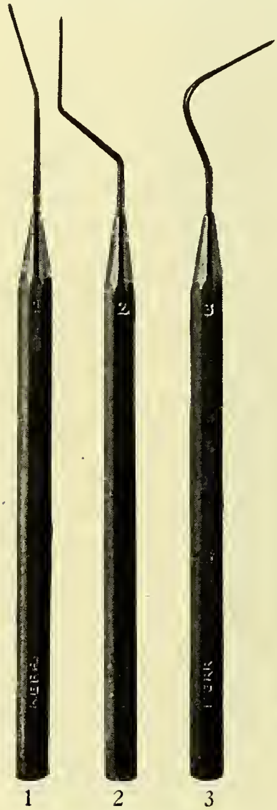


Fig. 1019.—Hall gutta-percha spreaders.

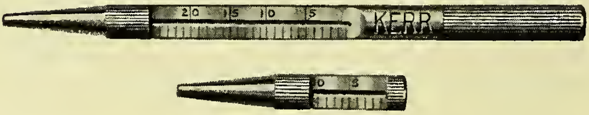


Fig. 1020.—Grove measurement control broach holders.

PRESENT DEVELOPMENT AND FUTURE PROGRESS

A study of the numerous methods and technical procedures at present advocated for the treatment and filling of pulp canals indicates the immense and renewed interest in the subject and a determination on the part of a rather small group of devoted men to solve the problems involved and to develop a more refined and operable technic. This is our greatest need at the present time. Many advances in our knowledge of the subject have been made during the past few years. A perusal of the extensive bibliography attached at the end of this chapter will prove this statement. A number of the modern technics for filling the canals are designed to overcome, as far as possible, the thermal expansion of the guttapercha, which results in shrinkage from the walls on cooling and also to eliminate, as far as possible, the use of solutions of guttapercha, such as chloropercha, eucapercha, etc., which are capable of still greater shrinkage on evaporation of the solvent used in mixing. The marked contraction of these substances was investigated by Doctor Weston A. Price and Doctor Dayton C. Miller and reported in the Journal of the American Dental Association, Vol. V, No. 12, Dec., 1918, pp. 1260. These important findings were ignored by many dentists until recently. These investigators found that eucapercha, used alone, shrinks about 24%, chloropercha, used alone shrinks approximately one-third its volume, chloroform and resin with guttapercha points, used after the Callahan technic exhibits an approximate shrinkage of 7.5%, while guttapercha used alone has a shrinkage of 1 to 2%. It would seem that guttapercha used alone or with a minimum amount of solvent is the best material so far discovered for filling root canals. Possibly a new material, possessing the necessary qualities for perfect adaption, with stability of form, may be discovered at an early date. If not, attention should be focussed on a method which will provide a less permeable floor to the cavity at its terminal or apical end, somewhat resembling the Hall preparation, and which will admit of the maintenance of pressure on the elastic guttapercha, until cool. This material is capable of elastic lock, similar to that of inlay waxes, which, if it can be applied, will greatly limit or eliminate its shrinkage. Perfect and permanent sealing of the inner ends of the tubules and accessory canals is necessary to prevent the passage of germs to the periapical tissues. These germs, if present in the tubules cannot pass through the impenetrable "fire-wall" afforded by the dentino-cemental junction in the gingival and middle thirds of the root. The development of a technic which will accomplish these results on the twenty anterior teeth in uncomplicated and favorable cases does not now seem to be an insurmountable difficulty for the average dentist. On the accomplishment of this, the further evolvement of the necessary skill to cope with similar cases in posterior teeth with favorable prognosis should be of comparatively easy accomplishment, certainly by the higher and better types of operator.

METHODS ADVOCATED BY THE AUTHOR

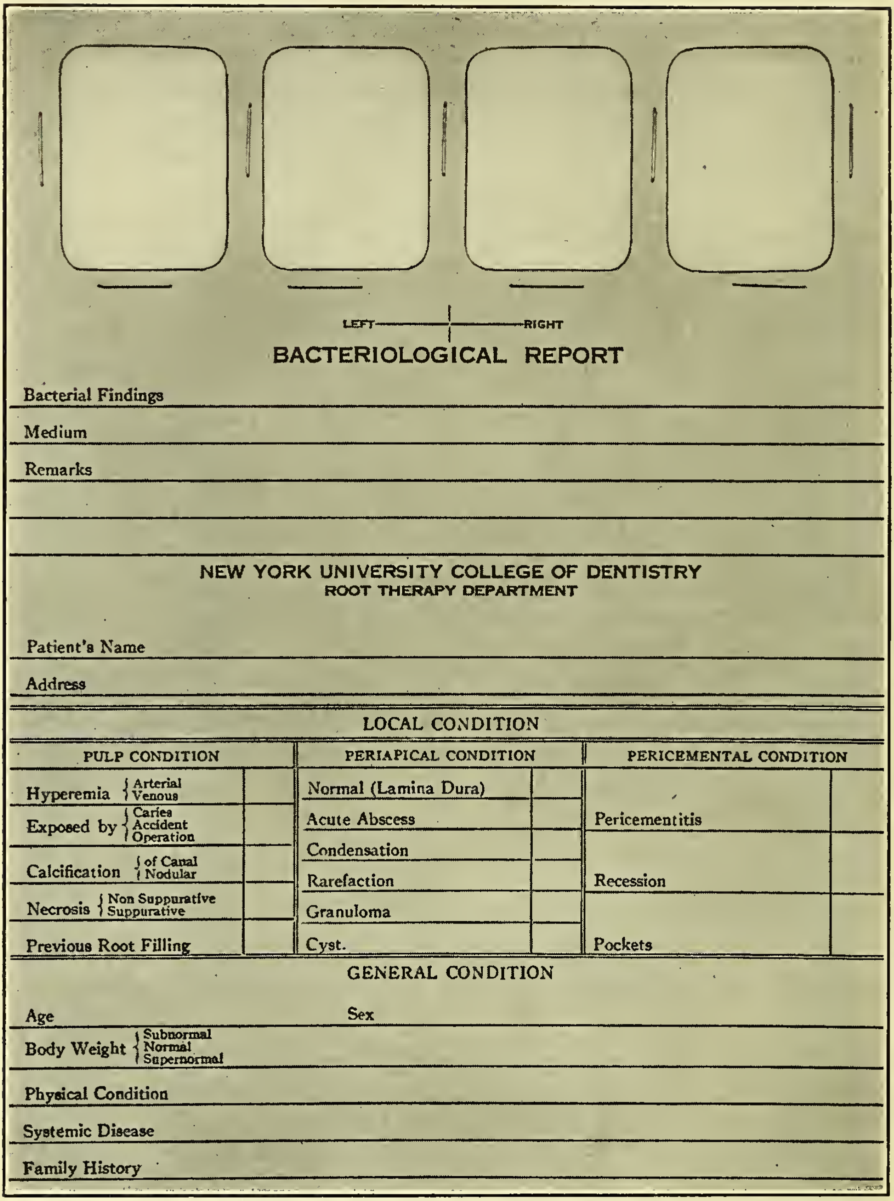
The method of treatment and filling of canals advocated by the author is herewith presented. This technic was largely developed by Professor Alfred S. Walker, of New York City. The results obtained in his clinic by students are rather unusual and are due to the performance of this technic under close supervision of Doctor Walker and his assistants. The Roentgenograms figured in this section show the results accomplished by his students.

PULP CANAL TREATMENT AND TECHNIC

For convenience, the description of this technic is made under the following headings:

Vital Cases.

1. First visit of patient.
2. Second visit of patient.



LEFT —— RIGHT

BACTERIOLOGICAL REPORT

Bacterial Findings

Medium

Remarks

NEW YORK UNIVERSITY COLLEGE OF DENTISTRY
ROOT THERAPY DEPARTMENT

Patient's Name

Address

LOCAL CONDITION

PULP CONDITION		PERIAPICAL CONDITION		PERICEMENTAL CONDITION	
Hyperemia { Arterial Venous		Normal (Lamina Dura)			
Exposed by { Caries Accident Operation		Acute Abscess		Pericementitis	
Calcification { of Canal Nodular		Condensation			
		Rarefaction		Recession	
Necrosis { Non Suppurative Suppurative		Granuloma			
Previous Root Filling		Cyst.		Pockets	

GENERAL CONDITION

Age Sex

Body Weight { Subnormal, Normal, Supernormal

Physical Condition

Systemic Disease

Family History

FIG. 1021.—Case history chart and film mount. On the reverse side (not shown) provision is made for recording the work done at each visit.

Non-vital Cases.

1. First visit of patient.
2. Second visit of patient.

Vital Cases.—I. First visit of patient.

Case History.—It is essential that a careful record of the procedure used in the treatment of the case be made. Such a record should include a mount for at least four X-rays of the case; provide for a diagnosis of the condition of the pulp, periapical tissues, and peridental membrane; and a bacteriological report. It should also include a personal history of the patient as regards age, general health and systemic condition. Fig. 1021.

Preparation.—A special operating tray should be prepared for the operator before beginning any pulp canal work as follows: (1) All operative instruments, such as mouth mirror, burs, college pliers, hand instruments, should be boiled and sterilized. (2) The root canal instruments, such as barbed broaches, smooth broaches, Kerr files, Rhein pics, also cotton points, cotton pledgets, gauze packs, etc., should be placed in a Kerr metal sterilizer and be autoclaved. (3) The tray should carry these and also a Sausser irrigator; novol dissolving cup; medicaments, such as iodin, distilled water, normal saline solution, eugenol, chloroform, formo-cresol; saturated solution thymol and alcohol diluted to one-half strength; Lugol's solution. Figs. 979, 980 and 981.

Anesthesia.—In the majority of vital cases, local anesthesia, either through infiltration or conduction injection of novocaine, is the best type to employ. When only partial anesthesia is obtained, or the injection fails entirely, pressure anesthesia is resorted to. In applying pressure anesthesia, the following precautions must be observed. The rubber dam must be applied, all debris and as much decay as possible removed and the pulp exposed. Sterilize the dentin in the cavity with either phenol or eugenol. A novocain pellet is applied directly over the exposure, dissolved by a drop of distilled water and pressed gently by a piece of unvulcanized rubber, which fits in to the cavity, until the patient feels no pain. Pressure anesthesia should never be applied to partially non-vital or suppurating pulps.

Treatment.—X-ray the tooth and mount in the case history. Apply the rubber dam to the tooth to be operated upon, and, if possible, include abjacent teeth. Paint the teeth and dam with tincture of iodin and wash off with alcohol.

Remove all decay and debris from the cavity. Sterilize the cavity with phenol.

Open and enlarge the pulp chamber with burs and excavators and, by removing sufficient tooth structure, proceed to gain direct access to the root canal.

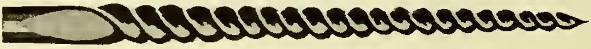


Fig. 1022.—Pulp canal file enlarged.

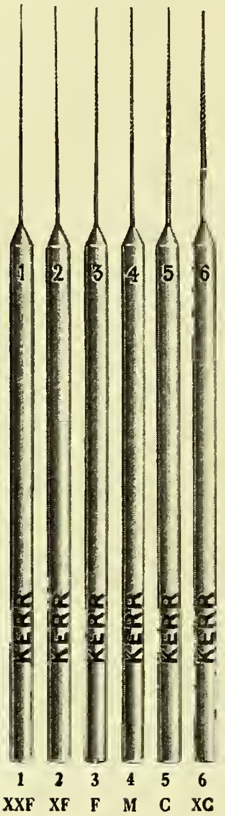
Having established access, so that the root canals may be entered with as little bending of the instrument as possible, select a new barbed broach of suitable size and carry it into the canal very gently until it meets with resistance. Then withdraw it slightly (about one or two mm.), rotate about three turns and withdraw.

This technic, when employed in canals of normal size and outline will usually enable the operator to remove the pulp *en masse.*

Tortuous or constricted canals should not be entered with barbed broaches until a plain broach has been passed freely to the point to which it is desired to carry the barbed broach.

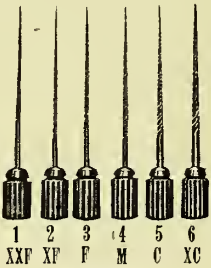
Hemorrhage following the removal of the pulp may be controlled by gentle flushing with warm saline solutions, and paper points for drying.

Enlarge the canal with Kerr files, proper sizes; also use a small amount of sodium and potassium alloy, follow with a small amount of sulfuric acid 35% solution, and wash out the canal with a sterile solution of sodium-bicarbonate. In using the chemicals, be careful not to penetrate to the apex. Figs. 1022, 1023 and 1024.



Style D

Fig. 1023.—Pulp canal files.



Style B

Fig. 1024.—Pulp canal files.

Dry the canal thoroughly with paper points and insert a measurement wire; then subject to the X-ray.

Remove the guide wire and place it in a small envelope and file with the case history for future reference. Place in the canal a paper point, the tip of which has been moistened with thymol-alcohol. Seal the dressing with base-plate guttapercha. This may be covered by a film of temporary cement as an added precaution against seepage. Dismiss the patient for 48 hours.

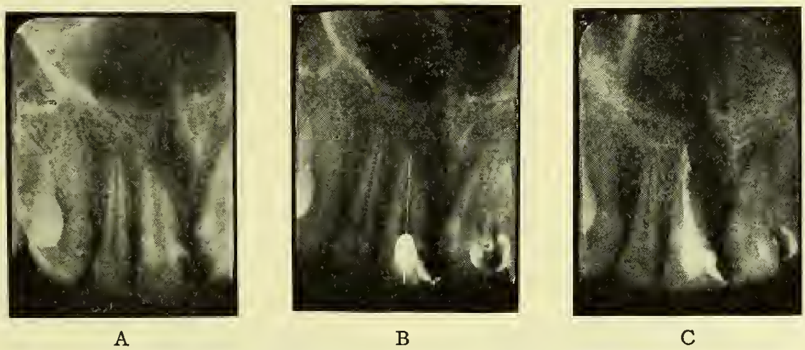


Fig. 1025.—Diagnosis in canal surgery. A, exposed pulp; B, measurement wire in position; C, canal filled. Patient age 14.

II. Second visit of patient.

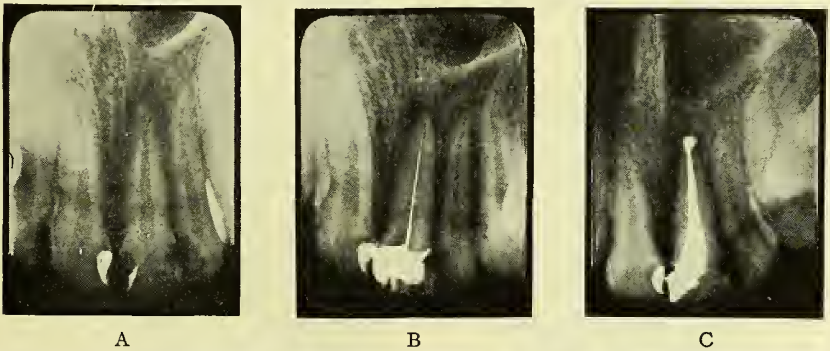


Fig. 1026.—X-ray diagnosis in pulp canal surgery. A, pulp exposure in patient age 12; B, measurement wire in place; C, root apex encapsulated.

Apply the rubber dam. Paint the teeth with tincture of iodin. Wash off with alcohol. Remove the dressing from the canal and wash out the canal with warm sterile distilled water. Check the second X-ray picture with the guide wire and, if the proper root length has been determined and the canal has been sufficiently enlarged it is ready for ionization.

Ionization.—In vital cases, ionize for a period of about 12 to 15 minutes, applying 1–2 milliamperes, using Lugol's solution. The canal is now ready for filling.

Filling.—Wash out the canal with pure alcohol and dry thoroughly with paper points. Use the X-ray, guide wire and the Kerr files employed in the case, as guides in determining the length and width of the canal. Select a guttapercha cone that will approximately fill the apex, cut off its apical third and attach it to a Kerr root canal plugger, which has been previously marked by a small rubber stop. Move the stop on the plugger until the length of the cone and plugger approximate that of the root canal. Flush the canal with chloroform, select a thin guttapercha cone and with a slight pumping motion in the canal, but short of the apex, mix a small amount of chloro-percha. Now take the previously prepared plugger and cone, place in the canal and with a slight rotary motion, seal the apex. With cones selected for proper width and cut into sections, fill the rest of the canal. Use Kerr pluggers with a rotary motion against the walls of the canal in order to condense thoroughly. X-ray and check the filling. Figs. 1025 to 1032.

Non-vital Cases.—I. First visit of patient.

X-ray the tooth and mount in the case history.

Apply the rubber dam to the tooth to be operated upon, and, if possible, include adjacent teeth. Paint the teeth and dam with tincture of iodin and wash off with alcohol.

Remove all decay and debris from the cavity and proceed to enlarge and cleanse the pulp chamber. Remove sufficient tooth structure to gain direct access to the root canal. With a barbed broach or Kerr file, enter only about 1 to 2 thirds the way into the canal and remove the debris. Be careful not to force any material through the apex or to clog the canal.

Dip the end of a paper point in formo-cresol (just a very small amount) and seal it into the canal. Dismiss the patient for 24–48 hours.

II. Second visit of patient.

Apply the rubber dam to the teeth, paint it with tincture of iodin and wash off with alcohol. Remove the dressing and now proceed to cleanse the rest of the canal of all material. Use Kerr files and follow by using a small amount of sodium and potassium alloy. Wash out with sterile distilled water. Follow this by using a small amount of 35% sulfuric acid and flush out with a sterile solution of sodium bicarbonate. Dry the canal thoroughly with paper points. Insert a guide wire and expose to the X-ray. Remove the guide wire and file it with the case history. Seal into the canal a formo-cresol dressing. Dismiss the patient for 24–48 hours.

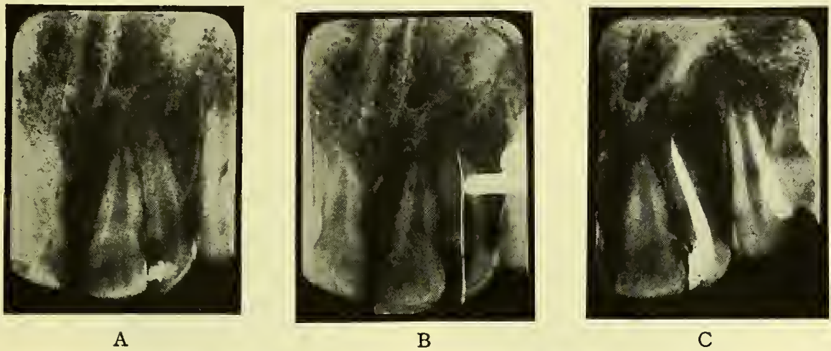


FIG. 1027.—Diagnosis in pulp canal surgery. Patient age 14. A, exposed pulp; B, measurement wire in place; C, canal filled.

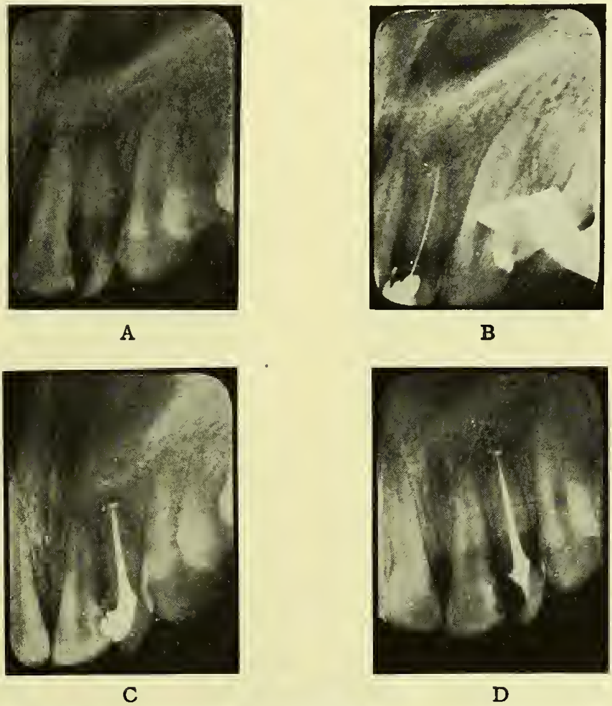


FIG. 1028.—Diagnosis in canal therapy. Patient age 15. A, suppurative pulp; B, test wire in place; C, canal filled, apex encapsulated; D, another view.

In those cases which present a moist gangrene or a serous or pus discharge, wash out the canal with sterile warm distilled water. Dry with paper points. Use a small amount of 35% sulfuric acid. Proceed to ionize the case.

Ionization.—In non-vital cases use Lugol's solution and proceed to ionize for about 20–30 minutes at ½ to 1 milliampere. Fill after ionization. In cases which present with periapical involvements or possible discharges, it may be necessary to repeat the ionic medication. Figs. 1033 to 1040.

Accidents are liable to occur through carelessness in opening canals. Perforation of the root, either laterally or via the apical foramen, breaking of broaches or reamers in the canal, and infection of the soft tissues may be the result.

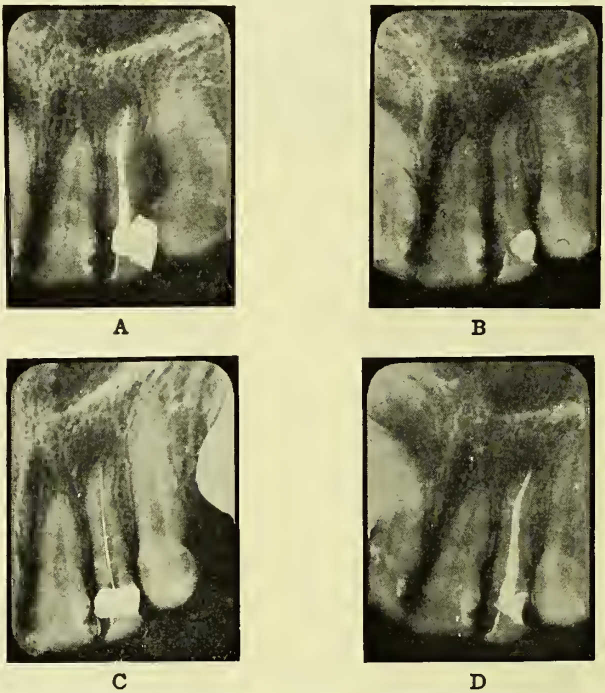


Fig. 1029.—X-ray diagnosis. A, old canal filling; B, filling removed; C, diagnostic wire in place; D, filled.

These should be avoided as far as possible by careful manipulation, aseptic methods, the avoidance of forcing infected pulp tissue through the apical foramen, the use of high-grade broaches and other instruments, careful testing and sterilizing of these before use, and avoidance of engine reamers wherever possible.

TECHNIC OF REMOVING BROKEN INSTRUMENTS FROM ROOT CANALS

If lying loosely in the canal, a new barbed broach, extra fine, sometimes may be passed to one side and the instrument "jigged" out.

A few shreds of cotton, wrapped on a small, smooth broach, will sometimes accomplish the same result. Moving the broken instrument back and forth, if it is loose, and pumping 50% sulfuric acid, phenolsulphonic acid, sodium dioxid, or sodium and potassium alloy about it will sometimes loosen it. Herman Prinz recommends 50% solution of nitric or nitro-hydrochloric acid. In some cases a small bur may be carefully used to drill around the instrument and help to loosen it. If the instrument is still tightly fixed in the canal, seal in for twenty-four hours sodium chlorid, Lugol's solution, tincture of iodin, or the previously-mentioned preparations, in the hope of chemically disintegrating the steel, when an attempt may again be made to dislodge it. In some instances the Howe or Beutelrock split and threaded instruments may prove serviceable. In case all attempts fail, the operation of apicoectomy may be attempted in suitable cases.

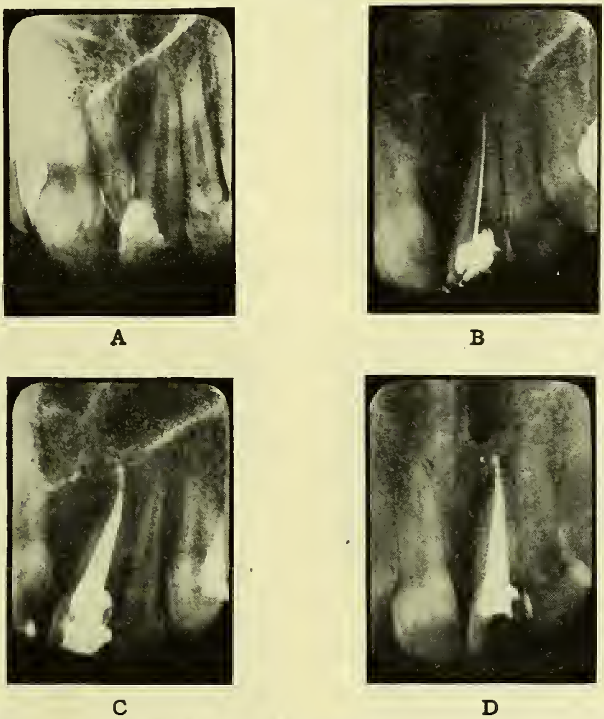


FIG. 1030.—Diagnosis. Patient age 11. A, suppurative pulpitis; B, test wire in place; C, canal filled, apex encapsulated; D, another view.

TECHNIC FOR REMOVING OLD CANAL FILLINGS

Guttapercha Preparations.—Heat a canal plugger or smooth broach. Soften the guttapercha with it and remove with barbed or twist broaches,

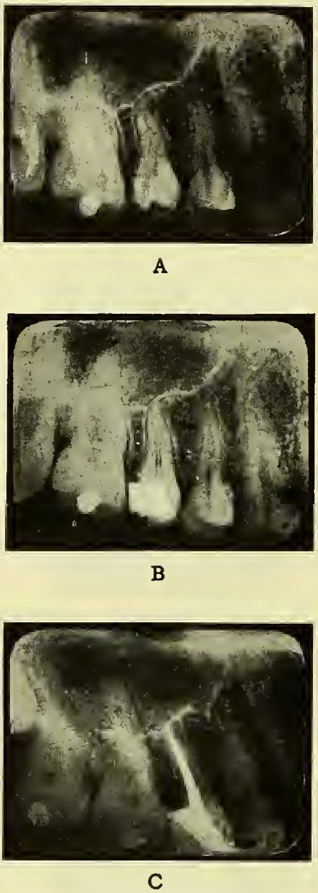


FIG. 1031.—Diagnosis in pulp canal therapy. A, pulp exposure; B, diagnostic wire in place; C, canal filled. Patient aged 15.

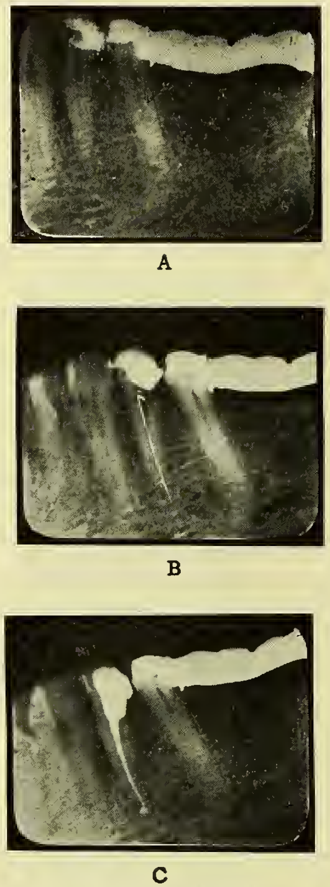


FIG. 1032.—Diagnosis. A, caries under filling. B, test wire in place; C, canal filled.

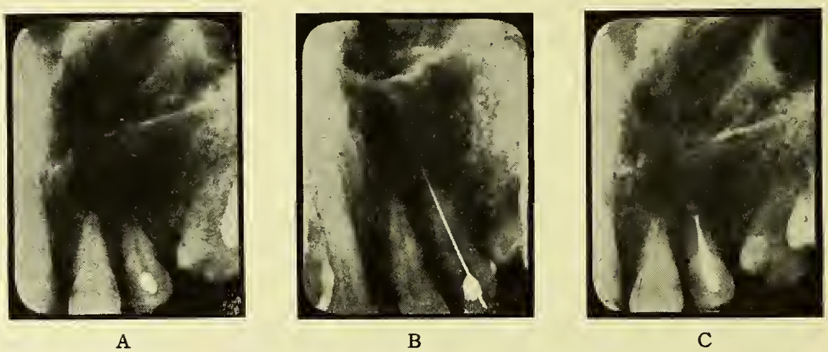


FIG. 1033.—X-ray diagnosis in pulp canal therapy. A, non-vital pulp; B, measurement wire in place; C, canal filled. Incorrect angulation.

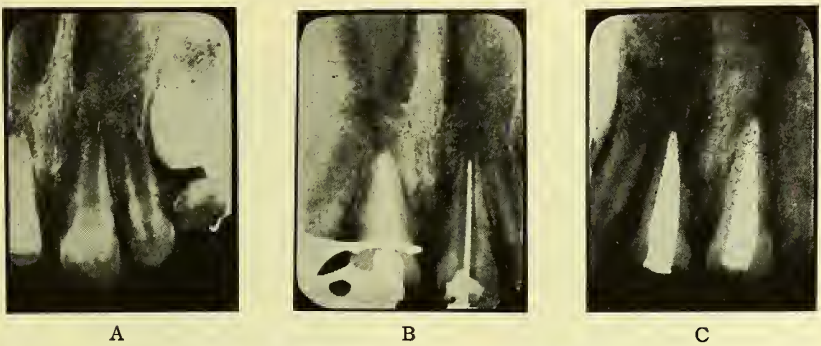


FIG. 1034.—Canal therapy. Patient age 11. A, pulp necrosis; B, one canal filled; measurement wire in other; C, both canals filled.

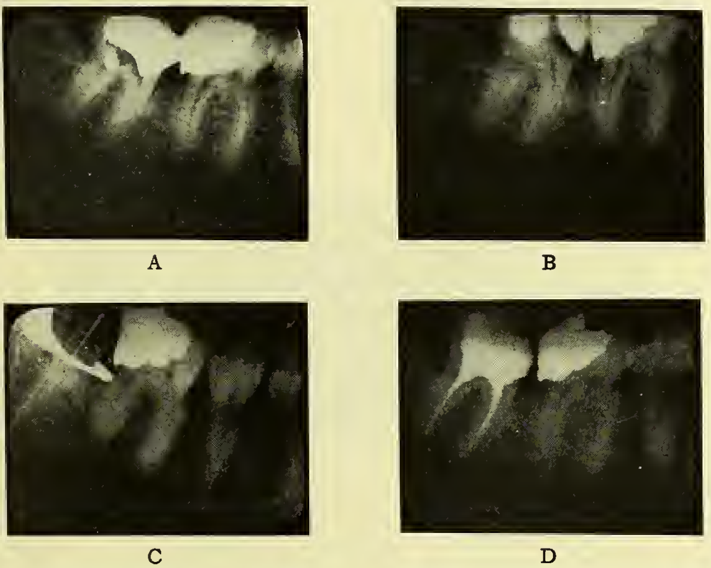


FIG. 1035.—X-ray diagnosis in canal therapy. A, Leaking filling and putrescent pulp; B, another view; C, wires in place; D, canals filled.

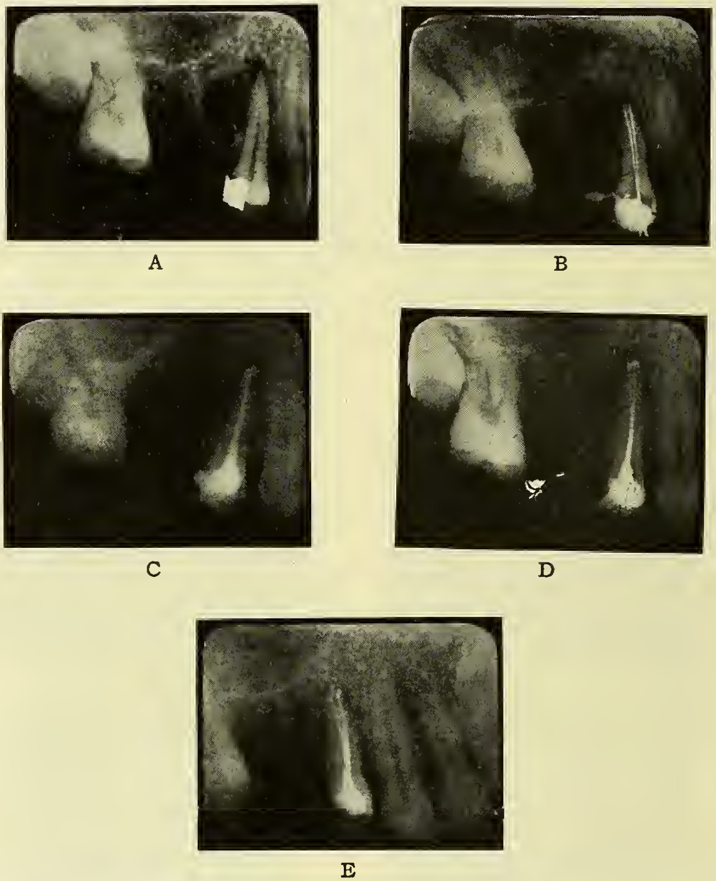


Fig. 1036.—X-ray diagnosis in canal surgery. A, putrescent pulp with rarefaction in periapical tissues; B, diagnostic wires in place in both roots; C, canals filled; D, rarefied area filling in with new bone; E, eight months later, further progress in bone condensation.

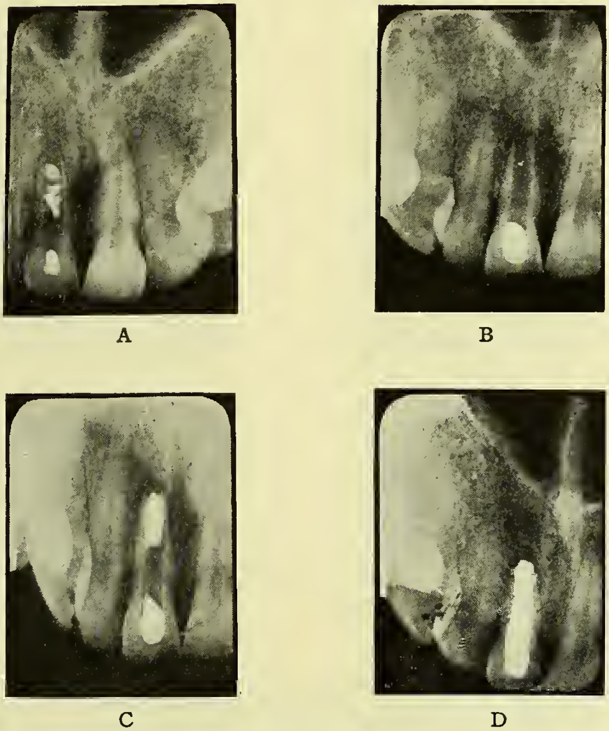


FIG. 1037.—Diagnosis in canal surgery. Patient age 20. A, poor attempt at canal filling before complete calcification of root; B, canal opened, measurement wire unnecessary owing to large size of canal; C, apical portion filled with guttapercha; D, filling complete.

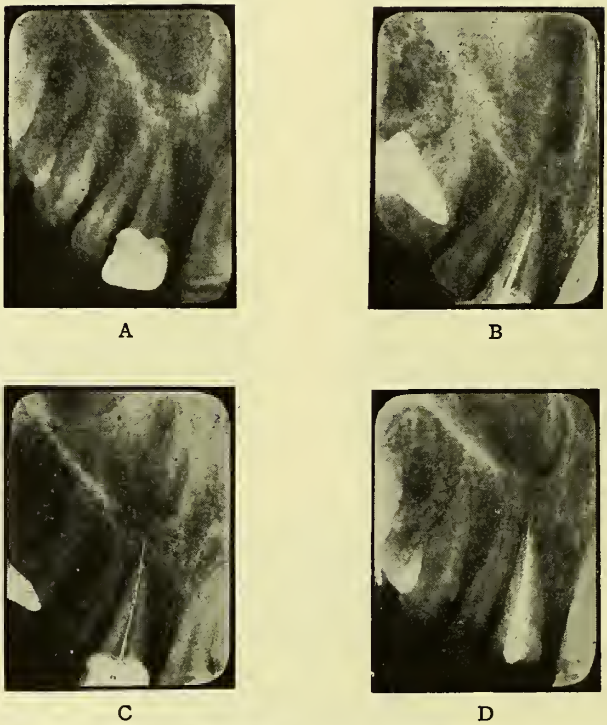


FIG. 1038.—X-ray diagnosis in canal therapy. A, putrescent pulp under gold crown; B, canal not opened to apex; C, measurement wire carried too far; D, canal filled.

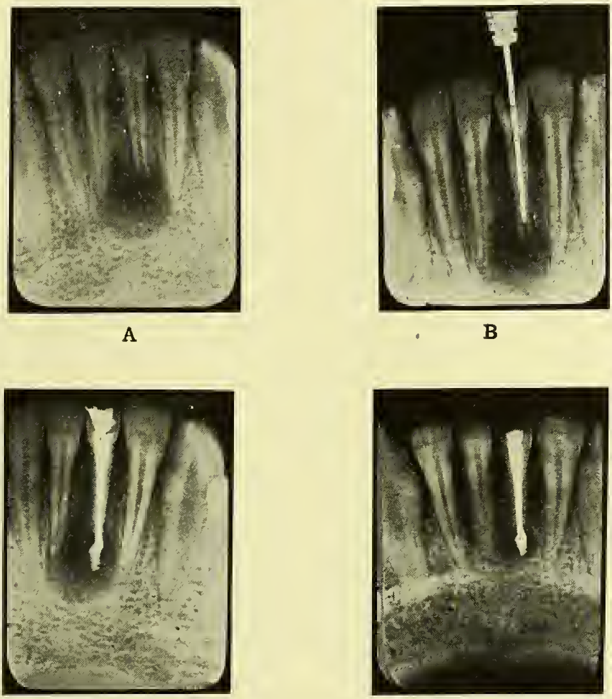


FIG. 1039.—X-ray diagnosis. Patient age 13. A, root cyst; B, diagnostic instrument in place; C, root canal filled, apex encapsulated; D, periapical tissues filling in with new bone.

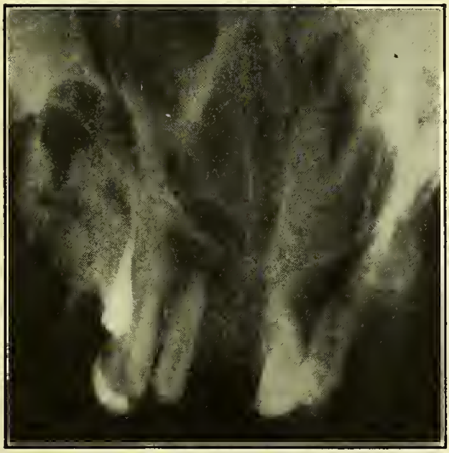


FIG. 1040.—Cysts.

continuing to heat and broach out the contents of the canal until all, or as much as possible, is removed in this manner. Chloroform, or preferably xylol frequently pumped into the canal will also be of assistance. In some instances it will be advisable, if the above methods fail, to seal in chloroform or xylol for twenty-four hours and continue the process at the next sitting.

Cement Preparations.—Soften with dilute sulfuric acid and remove with broaches in a similar manner to that described above. The sealing of the acid in the canal until the next visit often will be of assistance.

Paraffin and Wax Preparations.—Soften by heat and broach out.

Bibliography

1. Hunter, Wm.: Role of sepsis and antisepsis in medicine, London Lancet, Jan. 14, 1911, Dental Cosmos, July 1918, p. 585.
2. Price, Weston A.: "Dental Infections, Oral and Systemic," vol. 1 and 2, Penton Pub. Co., Cleveland, 1923.
3. Coolidge, Edgar D.: Preparation and filling of root canals, American textbook of Operative Dentistry, 6th ed., p. 567.
4. Blaney, J. R.: What teeth should be extracted, etc., Jour. Amer. Dent. Assoc., Vol. XV, no. 7, p. 1215.
5. Hall, Edouard M.: Mechanics of root canal treatment, Jour. Amer. Dent. Assoc., vol. XVII, no. 1, Jan. 1930, p. 88.
6. Buckley, J. P.: New methods and technic of filling root canals, Jour. Amer. Dent. Assoc., vol. XV, no. 11, Nov. 1928, p. 2069.
7. Grove, Carl J.: An accurate technic of filling root canals, etc., Jour. Amer. Dent. Assoc., vol. XVI, Sept. 1929, p. 1594.
8. Hatton, Edward H.: What teeth should be extracted, etc., Jour. Amer. Dent. Assoc , vol. XV, no. 7, p. 1222.
9. Skillen, Wm. G.: Status of the treated tooth, Jour. Amer. Dent. Assoc., vol. XIII, March 1926, p. 291.
10. Rickert, U. G.: My present conceptions for control of dental foci of infection, Dental Cosmos, vol. LXIX, no. 5, May 1927, p. 451.
11. Puterbaugh, P. G.: Root canal filling materials, Jour. Amer. Dent. Assoc., vol. XV, no. 2, p. 244.
12. Moen, O. H.: Tissue changes in teeth treated of known history, Jour. Amer. Dent. Assoc., vol. XV, no. 11, Nov. 1928, p. 2069.
13. Best, Elmer S.: The result of deep-seated caries in pulp canal involvement, Jour. Amer. Dent. Assoc., vol. 14, 1927, p. 1859.
14. Box, Harold K.: The dentinal cemental junction, Bulletin no. 3, Canadian Dental Research Foundation, May 1922.
15. Price, Weston A.: "Dental Infections," vol. I, Penton Pub. Co., 1923.
16. Buckley, J. P.: New method and technic of filling root canals, Jour. Amer. Dent. Assoc., Nov. 1928.
17. Rickert, U. G.: Fundamentals of successful root canal treatment, Jour. Amer. Dent. Assoc., vol. XIV, no. 9, Sept. 1927, p. 1657.
18. Coolidge, Edgar D.: Clinical results of root canal treatment, Jour. Amer. Dent. Assoc. March 1927, p. 493.
19. Blaney, J. R.: Jour. Amer. Dent. Assoc., vol. XV, no. 2, Feb. 1928, p. 203.

Hopewell-Smith, Arthur: Histologic characteristics of periapical tissue, etc., Jour. Amer. Dent. Assoc., vol. XV, no. 1, Jan. 1928, p. 54.

Hatton, Edward H., Skillen, Wm. G. and Moen, O. H.: Histologic findings in teeth with treated and filled canals, Jour. Amer. Dent. Assoc., vol. XV, no. 1, Jan. 1928, p. 56.

Blaney, J. R.: Medicinal treatment and filling of root canals, Jour. Amer. Dent. Assoc., vol. XV, no. 2, p. 239.

Price, Weston A.: Report of laboratory investigations of root filling materials, Jour. Amer. Dent. Assoc., vol. XV, no. 12, Dec. 1928, p. 2259.

Rosenow, E. C.: Oral sepsis in its relation to oral foci of infection and elective localization, Jour. Amer. Dent. Assoc., Aug. 1927, p. 1417.

Barker, Lewellys P.: Relationship of oral sepsis to disturbances of general health, Dental Cosmos, Jan. 1927.

Moorehead, Fred B.: Further observation of teeth involved in chronic infections, Jour. Amer. Dent. Assoc., vol. XV, no. 10, Oct. 1928, p. 1907.

MacMillan, Hugh W.: Structural characteristics of the alveolar process, Internat. Jour. Orthodont., Oral Surgery and Rad., vol. XII, no. 8, Aug. 1926.

Brooks, Matilda N. and Price, Weston A.: Relative efficiency of medicaments for sterilization of root canals, Jour. Nat. Dent. Assoc., vol. V, no. 3, March 1918, p. 273.

Skillen, Wm. G.: The pulpless tooth from a histologic standpoint, Jour. Amer. Dent. Assoc., vol. XIV, no. 3, p. 500.

Box, Harold K.: Histological and histo-pathological studies of the dental pulp, Bulletin no. 4, Canadian Dental Research Foundation, May 1922.

Rickert, U. G., Blaney, J. R. and Miner, LeRoy M. S.: Symposium on the pulpless tooth, Jour. Amer. Dent. Assoc., May 1929, pp. 840–866.

Grove, Carl J.: Why root canals should be filled to the dentino-cemental junction, Jour. Amer. Dent. Assoc., Feb. 1930, p. 293.

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